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THE ROYAL UNIVERSITY OBSERVATORY IN STRASSBURG.

H. C. WILSON.

Our Frontispiece is copied from a beautiful photo-engraving contained in the first volume of the annals* of the new Observatory at Strassburg. The view is taken from the garden of the Observatory and shows in the center the dome for the great equatorial, at the right the meridian house with two domes attached, and at the left the astronomers' dwelling house. The three buildings are situated approximately at the vertices of an equilateral triangle, about 200 feet apart. They are connected by covered walks which meet in the center of the triangle, so that the astronomers may pass from one building to the other without fear of rain or sun.

The great equatorial has an aperture of 487 millimeters (about 19 inches) and a focal length of nearly 7 meters (23 feet). The objective is by G. & S. Merz, in Munich, and the mounting by the Repsolds in Hamburg. The equatorial building is of the shape of a symmetrical cross, surmounted at the center by the dome, which is 30 feet in diameter. Around the base of the dome on the outside is a wide balcony from which the astronomers may search for comets with a small comet-seeker, which instrument is mounted upon a rolling chair of such construction that the observer in sweeping the sky moves himself bodily with the telescope, instead of straining back and neck, as must be done with the ordinary form of comet-seeker.

The meridian house is of an L-shape with two small domes surmounting the short arm of the L. The two domes shelter, the one a 6 inch Repsold refractor, the other a 5 inch altazimuth instrument by Merz. In the building are also a Repsold meridian circle, a broken transit, and a number of auxiliary instruments. In a small building not shown in the picture there is also a heliometer.

An interesting feature we notice about all the instruments is that the piers which support them are hollow, with openings

* Annalen der Kaiserlichen Universitäts-Sternwarte in Strassburg. E. Becker. Erster Band. Karlsruler, 1896.

which permit the free circulation of air through them, so that there is a tendency toward rapid equalization of temperature throughout their masses. The foundation of the great equatorial is really the same as that of the dome, the two being separate only in the upper part of the middle story. There is quite a large circular room directly below the telescope within the pier, and in the basement a smaller room surrounded with thicker walls is called the "room of constant temperature." This room is arranged to be heated by gas so as to keep it actually at a constant temperature, but we infer that this has not been found necessary, since the change of temperature is so gradual and the total range in the last seven years has been only 19° *C*. Two of the principal clocks of the Observatory are kept in this room.

The arrangement and equipment of the Observatory were planned principally by the eminent astronomer, Dr. August Winnecke, who was appointed to the chair of Professor of Astronomy in the University of Strassburg in 1872. The present buildings were erected in the years 1877 to 1880, and practical work in them was begun in 1881, although a good deal of work had been done in a temporary Observatory before that time. Dr. Winnecke died May 31, 1886, having enjoyed but for a short time the use of the splendid institution which he had built up. His successor Dr. E. Becker with the aid of able assistants has carried on with vigor the work originally planned. The first volume of the *Annals* issued in 1896 contains, besides the description of the Observatory, the results of the observations made with the meridian circle from 1882 to 1886 inclusive.

THE STUDY OF THE VARIABLE STARS. VI.

PAUL S. YENDELL.

For Popular Astronomy

1090 β Persei (*Algol*). 1.

As the oldest and best known variable except Mira Ceti, and as the type-star of an important class, of which the number known to us is continually growing; and as the star, the laws and cause of whose variations have been the most completely worked out of any, it seems peculiarly fitting that Algol should find a leading place in the present series of papers.

Being one of the bright stars in the constellation Perseus, it has been well known to astronomers since the stars began to be ob-

served. Its Arabic name, *Al Ghul* (the Demon), may convey a hint that something peculiar was early noticed about it, and that the behavior of "this slowly winking eye" was to some degree known before modern astronomy began.

It is certain that its variability was known for more than a century before its real character was discovered, but did not attract much attention, on account of its apparent irregularity.

Argelander observed this star assiduously, and the foundation of our accurate knowledge of it is due to him. In Vol. VII of the Bonn Observations he has given a complete and elaborate history of the star, of which the following account is substantially a translation.

The first notice of this star's variability appears in a little treatise of Montanari's "*sopra la sparizione d'alcune stelle et altre novità celesti*," published, according to Weidler and Lalande, in 1672. He says: "if you look occasionally (*punto*) at the dreadful head of Medusa, you will perceive that the brightest star that shines there passes through surprising changes, and only at alternate seasons does it possess its greatest light. For many years I observed it as third magnitude. It diminished in 1667 to the fourth light; in 1869 it resumed its former brightness, being of the second honor; and in the year 1670 it went a little beyond the limits of the fourth." Had Montanari only quoted even the day on which he saw the star of the fourth magnitude!

Maraldi confirmed this discovery: in the year 1694 he had seen the star sometimes of the fourth, sometimes of the third, and very often of the second magnitude, but it did not occur to him to look for a regularity like that of Mira Ceti in these light-changes, apparently for the reason that the times of equal lights seemed to be too irregularly distributed, and he did not think of so short a period as is really the case.

This fine discovery was reserved for Goodricke, by whom it was made in the year 1782. It awakened well deserved interest, and astronomers vied with each other to confirm it, and to follow it up with continuous observations. Much credit for the support and encouragement of this zeal belongs to Wurm, for his successive improvements on the elements of variation, and predictions of the times of minima.

Thus it happens that we have a great mass of observations, mostly very good, about the end of the last century, by the discoverer himself, his friend Pigott, Herschel, Lalande, Englefield, Wurm, and others. But with the year 1800, the interest began

to flag; Wurm himself paid the star less attention than at first, although he continued to compute ephemerides of minima. Besides him, there were only Bode, Luthmer, and Harding who from time to time turned their attention to the star. That Bessel himself observed two minima, he himself informed me* when I made known my first researches on the star; and I have recently found among Olbers' papers a minimum observed by him. Since 1840, I have undertaken to follow up the star; first Heis came to my support, then Schmidt and others of my younger friends, and in the last fifteen or twenty years (the paper seems to have been written about 1866) observations have multiplied themselves to an extraordinary degree, so that for almost every year well-determined epochs can be based on very numerous observations.

The observations of Montanari and Maraldi would probably be difficult to find, even if these astronomers actually noted times, which seems to me doubtful. I have looked into the various older collections of observations, to see if by any chance I could find any data from which a minimum might be inferred, but have found very little. Tycho observed our star very frequently, in various positions, even at the lower culmination, but he has not given a single magnitude. The single observation from which a negative result might possibly be inferred is the meridian altitude observed 1587 Jan. 14, O. S. Since he had observed the meridian altitude of ρ Persei immediately before this, it would seem that, if β had not been in a marked degree brighter than ρ, it must at once have attracted his attention, as he apparently counted the former star among the brightest in the sky, as his many observations of the star, which he frequently used as a comparison-star for others, and for the determination of the instrumental error, go to show.

A similar negative result may probably be drawn from two observations of Hevel's, who also observed Algol very frequently, but always without giving magnitudes; on 1671, Oct. 4, he measured its distance from the fifth magnitude star π Persei, 2° distant; if Algol had at the time been only a single magnitude brighter than π, it must certainly have attracted his notice, since in 1658, Oct. 2, he had observed its distance from Polaris, to which Algol is very nearly equal at its normal light.

Flamsteed has given no magnitudes with his measures of distance. Of the ten days on which these appear, eight in the constellation Perseus and two in Cassiopea, two, 1680, Oct. 21, N. S.

* Argelander; in this part of the paper, the personal pronoun is used as A. used it.

and Nov. 2, N. S., occur on the days of minima, and in the future when the periodic inequalities of the star's variation shall be better known than at present (1866), these may be used as checks, if the assumption be allowed that Flamsteed was careful about his magnitudes, and attached a certain value to them. That this, however, was not the case, is shown by a comparison of the magnitudes in the *Catalogus* Brittanicus with those given with the quadrant observations; for the brighter stars, they often disagree entirely, and no controlling weight can be assigned to the estimates made with this instrument. For our star, these, reduced to New Style, are: 1693, Dec. 29, 2^m; 1696, Jan. 26, 3^m, ρ at the same time 4^m; 1711, Dec. 16,3^m, but ω at the same time 6^m, o 5^m, o 6^m, n 7^m and ζ 3^m. So that on this last date the estimates are generally too faint, (the D. M. magnitudes are respectively 5.2^m, 4.8^m, 3.8^m, 5.8^m, 3.0^m) and the star cannot have been far from the maximum; by my tables, the minimum actually occurred a day later. I doubt whether, with Wurm, we can give significance to the observation of 1696, Jan. 26, and assume that Algol was then not far from its minimum. Certainly, according to my tables above mentioned, the observation falls only nine hours before the minimum, and a slight change in the assumed period would bring it still closer. But I do not believe that any use can be made of this observation.

Among Christopher Kirch's manuscripts, I have found a remarkable observation, 1733, Oct. 2. After noting an observation of Mira Ceti between 9^h and 10^h, he says: "Hevelius in Prodr. Astr. p. 123 says among other things as follows; '10. *Algol Medusae fere eiusdem magnitudinis reperta est cum latere dextro Persei.*' I found the same today noticeably smaller, and only about of equal magnitude with δ Persei."

He makes the following marginal note to this; "I must have been a trifle careless here, since I have noted Algol not much fainter than α Persei, and markedly brighter than δ, several times this autumn." But he was not careless, as he himself might have seen, since he noted at the time the discordance with Hevel. On that evening Algol was really at minimum, according to Wurm's table about 6^h 23^m, and to mine about 5^h 23^m, Berlin Mean Time. What a pity that Kirch did not give the time more exactly!

Bradley and Mayer, as is known, only estimated magnitudes for "anonyma" (stars not lettered nor numbered in existing catalogues). But among their earlier observations, two appear which give a negative result as to the time of minimum; namely,

he observed Algol in the quadrant below the pole, at a zenith distance of 88° 13′, on 1751 Jan. 6, 7 and May 18, O. S., and at the first and last observations he has expressly noted "bright."

A remarkable observation is found among D'Agelet's. He observed Algol six times, three times without, and three, 1784 Oct. 6, 9, 15, with magnitudes. On Oct. 6 he has estimated the star as 4^m, on the other two dates, $2^m.3$. On the first date, the star was on the meridian at about $14^h\ 1^m$, Paris Mean Time, but according to the ephemeris, the minimum on that day fell at $5^h\ 37^m\ 45^s$, Paris Mean Time, so that the observation comes more than eight hours after the minimum, at which time the star is again at its full light, $2^m.3$. In view of the regularity of the star's variation, which has been shown at all its appearances for much more than eighty years, so great an anomaly is incredible, as is also a later occurrence of the minimum, since the observed times on Aug. 21, Sept. 7, 10, 13, 30, Nov. 15, 18, fall within the limit of the probable errors of observation from the computed times.

It must also be taken into consideration that D'Agelet, probably from Méchain's computations, knew that a minimum was due on Oct. 6, and, being influenced by this preconceived idea, estimated the star as thus faint. It is certainly remarkable that he had, just previous to this observation, estimated ρ as $4^m.0$, but as I consider, this is a new proof of the fact that estimates of magnitude made with the telescope are always very uncertain, even when the greatest care is taken, and much more so when made with the slight attention which was at that time paid to magnitude estimates, when these were not the especial object of the observations. (Argelander's reference is undoubtedly to eye-estimates, as his remarks do not apply to careful comparative estimates).

How easy it is to make such an error is shown in a striking manner in Bugge's observations. This astronomer, not without reputation in his time, believed that he could determine star magnitudes accurately by means of estimates of the diameters of their optical discs, as compared with the thickness of his eyepiece wires, when placed behind them. His observations accord very finely with his own computed times of minima; but unfortunately he has in these computations made an error of a day in the interval between two consecutive minima, so that it happened that he obtained a period about eighteen minutes too long. Naturally, I have not been able to use the observations.

Piazzi's determinations are rot of great value, since they fall during a time when we have a great number of certain determin-

ations. He frequently observed Algol, but only estimated its magnitude in the Circle series CXXIII, observed 1799, Jan. 2, 3, 8, 10, and CDXIX, observed 1809 Nov. 24, 29, and both times as $4^m.5$; in the second series ρ also as 4^m. Minima occurred, according to the tables, 1799 Jan. 8, 8^h 43^m, Palermo Mean Time, 1^h 1^m after the observation, and 1809 Nov. 29, 8^h 51^m Palermo Mean Time, 1^h 31^m before the observation. But on both dates the star must have been considerably brighter than $4^m.5$, and the low estimate must certainly have been by reason of its faintness in comparison with its usual brightness. How little importance Piazzi assigned to his magnitude estimates may be seen by the fact that he noted the magnitude as the same on other dates, when it is certain that the star was not below its normal brightness.

The observed dates, from the recognition of the star's periodicity until 1866 Feb. 16, are assembled by Argelander for his discussion of its elements; they number in all 163. In Chandler's discussion, to be referred to later, he collects, including those gathered by Argelander, nearly seven hundred minima, the latest date being 1887 Dec. 5. The published observations since this date may be found in the various astronomical periodicals, especially the *Astronomical Journal* and the *Astronomische Nachrichten*. Plassmann, of Warendorf, has also published his own observations in several small pamphlets.

Although the star has been, on the whole, well followed up, and our knowledge of it is the least incomplete that we have of any variable, there are still points about it to be cleared up, and there is work for the observer throughout its entire period. It is not a difficult star to observe, being even at minimum, conspicuous to the naked eye, and the use of an opera glass enables observations to be carried on through the time of full Moon: for nine months in the year it is observable during the evening hours, and there is no season when it cannot be observed at some part of the night. Careful observations of its brightness throughout its whole period, especially from three to six hours before and after the minimum, will be of great value, and it is hoped that some observers may be interested to make them.

DORCHESTER, Mass.,
1897 July 6.

GEGENSCHEIN OBSERVATIONS.—1895-6

A. E. DOUGLASS.

FOR POPULAR ASTRONOMY.

The following table contains a collection of observations upon the Gegenschein, made chiefly at Flagstaff in the spring of 1895 and the autumn of 1896. The observer is the writer in every case not specially noted. The localities from which the observations were made are as follows:

	Longitude. h m	Latitude. ° ′	Elevation. ft.
Flagstaff, Arizona, U. S. A.	7 27	35 11	7250
Mexico City, Mexico	6 36	19 25	7475
(Near) Ojo Caliente, Mexico	7 06 ±	30 20 ±	4200
(Near) Cañitas, Mexico	6 51 ±	23 50 ±	6500

No.	Date.	G. M. T.	Loc. App. Sol. Time	λ	$\Delta\lambda$	β	Diam.	Remarks.
	1895.	h m	h m	°	°	°	°	Flagstaff.
1	Feb. 19	19 08	11 27	152.6	+ 1.2	+ 0.2	4	
2	21	15 58	8 17	135.0	− 78.3	+ 0.5		(Doubtful Ident.)
3		15 58	8 17	154.0	+ 0.7	+ 0.8		
4		18 46	11 05	153.3	− 0.1	+ 3.7		
5		18 46	11 05	154.0	+ 0.6	+ 0.8		
6	Mar. 17	18 17	10 42	170.2	− 7.3	+ 1.4	13	(Doubtful Ident.)
7		18 42	11 07	174.1	− 3.4	+ 0.5	4	
8	19	18 56	11 21	177.2	− 2.3	+ 2.9	4	
9	20	19 35	12 01	180.9	+ 0.5	+ 1.5	6	
10	21	18 53	11 19	183.1	+ 1.7	+ 1.7	9	
11		19 42	12 08	183.1	+ 1.7	+ 1.7	9	
12	22	18 31	10 57	181.8	− 0.6	+ 1.6	6	
13		19 11	11 37	182.4	0.0	+ 2.6	7	
14	23	17 00	9 27	183.6	+ 0.3	+ 3.5	4	
15		20 05	12 32	183.2	− 0.2	+ 1.7	3	
16		22 24	14 51	183.0	− 0.5	+ 0.7	6	
17		23 04	15 31	183.1	− 0.5	+ 4.3	5	
18	24	17 33	10 00	186.3	+ 2.0	+ 0.7	5	
19		17 39	10 06	184.2	− 0.1	− 0.9	5	
20	27	19 08	11 36	187.9	+ 0.5	+ 1.1	5	
21	28	18 37	11 05	188.4	0.0	+ 1.2	4	
22	29	18 01	10 29	190.7	+ 1.3	+ 0.5	6	
23	30	18 20	10 49	192.2	+ 1.9	+ 0.9	6	
24		18 20	11 11	189.7	− 0.6	+ 1.5	4	By G. Sykes.
25		18 20	11 11	180.5	− 3.7	+ 11.3	2	(Doubtful Ident.) By S. Sykes.
26		21 15	13 44	191.9	+ 1.5	+ 2.1	3	
27	31	19 37	12 06	194.6	+ 3.3	+ 2.3	8	
28	Apr. 1	21 15	13 44	192.5	+ 0.1	+ 2.7	—	
29		21 28	13 57	192.5	+ 0.1	+ 2.7	3	
30		21 28	13 57	192.5	+ 0.1	+ 2.7	—	By J. C. Grim.
31	2	21 12	13 42	195.5	+ 2.1	+ 0.9	3	Moon barely set.
32	14	17 10	9 43	205.8	+ 0.8	+ 1.8	3	
33	15	18 39	11 12	210.1	+ 4.0	+ 2.0	7	
34		19 15	11 48	208.4	+ 2.3	+ 1.0	5	
35	16	17 12	9 45	209.5	+ 2.6	+ 3.3	7	Low in E.
36		18 12	10 45	210.9	+ 3.9	+ 1.7	4	
37		19 09	11 42	208.8	+ 1.8	+ 0.9	7	
38	17	16 23	8 57	211.4	+ 3.5	+ 1.7	4	
39		18 48	11 22	209.4	+ 1.4	+ 1.2	6	

No.	Date.	G. M. T.	Loc. App. Sol. Time	λ	$\Delta\lambda$	β	Diam.	Remarks.
	1896.	h m	h m	°	°	°	°	
40	18	18 40	11 14	212.0	+ 3.0	+ 2.1	8	
41	19	18 33	11 07	212.6	+ 2.6	+ 2.4	4	
42	20	17 48	10 22	214.0	+ 3.2	+ 2.6	6	
43	21	19 30	12 04	215.1	+ 3.2	+ 2.2	10	
44	22	18 50	11 25	214.3	+ 1.4	+ 1.6	2	
45		20 55	13 30	214.0	+ 1.0	− 0.2	2	
46	23	18 45	11 20	215.3	+ 1.4	+ 0.5	3	
47	24	18 30	11 05	216.1	+ 1.3	+ 1.1	4	
48	25	17 10	9 45	216.4	+ 0.7	+ 2.6	5	
49		18 03	10 38	216.4	+ 0.6	+ 2.6	5	
50		18 03	10 38	217.1	+ 1.3	+ 2.0	1	
51	26	18 32	11 07	219.9	+ 3.1	+ 1.8	7	
52	27	18 00	10 36	222.0	+ 4.2	+ 6.0	4	
53	28	18 55	11 31	222.9	+ 4.2	+ 4.6	5	
54	May 20	18 26	11 54	236.7	− 3.3	+ 1.3	4	Mexico.
55	1896 21	18 56	12 24	237.3	− 3.6	− 0.6	7	
56	Sept. 10	16 35	9 11	347.6	− 1.3	− 0.8	5	Flagstaff.
57		19 13	11 49	347.6	− 1.4	− 1.9	7	
58	11	18 50	11 27	352.9	+ 2.9	− 0.2	3	
59	12	18 27	11 04	354.4	+ 3.4	+ 0.8	7	
60	13	17 55	10 32	354.9	+ 3.0	− 0.3	6	
61		17 55	10 32	351.2	− 0.7	− 0.3	20	By Dr. See.
62		17 55	10 32	351.6	− 0.3	− 0.2	8	By W. A. Cogshall.
63		20 30	13 07	352.7	+ 0.7	+ 0.8	6	
64	14	19 30	12 08	355.6	+ 2.7	− 1.3	6	
65	15	21 12	13 50	359.2	+ 5.2	− 3.2	5	
66		23 42	16 20	1.6	+ 7.5	− 3.0	6	(Late)
67	17	22 15	14 54	2.2	+ 6.2	− 3.1	5	
68	Oct. 1	18 15	10 59	10.2	+ 0.6	− 1.5	8	
69	2	17 40	10 24	14.2	+ 3.7	− 2.5	4	
70	3	16 50	9 34	19.2	+ 7.7	− 2.5	4	
71		20 12	12 56	14.8	+ 3.2	− 0.2	4	
72		23 21	16 05	13.2	+ 1.4	− 2.4	—	Crescent Moon.
73	4	18 32	11 16	16.0	+ 3.4	− 2.2	5	Geg. very low.
74		18 38	11 22	16.0	+ 3.4	− 2.2	—	
75	5	16 17	9 02	18.9	+ 5.4	− 2.3	7	
76		17 30	10 15	16.1	+ 2.6	− 1.3	7	
77		22 23	15 08	16.3	+ 2.6	− 1.3	5	
78	6	23 45	16 30	19.2	+ 4.5	− 3.0	5	Very low in W.
79	7	17 13	9 58	17.9	+ 2.5	− 2.8	6	
80	8	17 07	9 53	19.6	+ 3.2	− 3.7	7	
81	9	17 02	9 58	19.1	+ 1.7	− 2.8	7	
82		20 32	13 18	17.4	− 0.2	− 1.3	6	
83	10	17 48	10 34	16.9	− 1.5	− 2.0	4	
84	15	21 11	13 58	22.9	− 0.6	− 0.9	4	
85	17	22 58	15 46	23.8	− 1.7	− 1.2	5	Low in west. Moon
86	27	17 55	8 44	39.4	+ 4.1	− 3.3	6	barely set.
87	28	16 05	8 54	37.9	+ 1.6	− 4.5	5	Elongated.
88		17 25	10 14	37.9	+ 1.6	− 4.5	5	"
89	29	16 30	9 19	38.8	+ 1.5	− 1.4	7	
90	30	17 39	10 28	41.2	+ 2.9	− 3.5	6	Unusually bright.
91	31	18 28	11 17	43.9	+ 4.5	− 2.7	6	
92	Nov. 1	16 30±	9 19±	45.9	+ 5.6	− 2.6	8	
93	2	19±	11 50±	45.8	+ 4.4	− 2.8	4	Elongated and stellar light may interfere.
94	3	18±	10 50±	43.5	+ 1.1	+ 1.3	3	Eccentric.
95	5	15 50	8 39	43.5	− 0.8	+ 1.3		Near Ojo Caliente, Mexico. Doubtful.
96		15 50	8 39	47.1	+ 2.8	− 4.7	2	Nucleus.
97	6	15 25	8 14	47.0	+ 1.8	− 5.0		Near Cañitas, Mexico. Doubtful.
98	7	18 55	11 44	43.6	− 2.8	− 1.0	3×6	Mexico City. Doubtful.

Upon gathering these observations together by lunations and discarding a few which are probably in error, we obtain the following table of means:

TABLE OF MEAN PLACE OF GEGENSCHEIN FOR EACH LUNATION.

LUNATION.	MEAN DATE.	NO. OF OBS.	λ	$\Delta\lambda$	β
I.	1895 Feb. 24	4	154	+ 0.6	+ 1.4
II.	Mar. 26	24	186	+ 0.4	+ 1.8
III.	Apr. 25	22	214	+ 2.3	+ 2.1
IV.	May 24	2	237	− 3.4	+ 0.4
V.	1896 Sept. 7	11	354	+ 1.8	− 0.9
VI.	Oct. 6	15	17	+ 1.9	− 1.9
VII.	Nov. 5	13	43	+ 2.2	− 2.6

With the exception of the final lunation these observations distinctly sustain Professor Searle's discovery that the path of the Gegenschein is inclined about 2° to the ecliptic, and that its ascending node is in some region not far from 90° of longitude. During the last lunation the Gegenschein closely approached the Milky Way in Taurus and its error in latitude is probably due to its being confused with the outlying portions of that light, which in that region extend to a considerable distance from the main stream.

Upon combining these means with the means of 157 previous observations, made almost entirely by the writer while connected with the Harvard College Observatory, making a total of 254 observations, the result indicates that the path of the Gegenschein is inclined between 1°.7 and 2°.0 to the ecliptic and has its ascending node at about 135° of longitude, 115° and 155° being the probable limiting values.

A minute study of this large collection of observations indicates that observations before 8^h and after 16^h of local apparent solar time are practically worthless for determining the position of the Gegenschein. Upon discarding about twenty-five observations out of the 254, most of them for being outside these limiting hours, and assigning the Gegenschein an orbit as given above, it appears to have a mean observed position of − 0°.02 in latitude, which presumably indicates no departure from a mean place on the ecliptic, and + 0°.63 in longitude, or − that amount in advance of the point opposite the Sun. The average residual in latitude per observation is a trifle over 1°.0 and in longitude several times that amount. Upon testing for parallax between 92 observations made in 16° south latitude and 137 made nearly all at 35° or 42° of north latitude, a negative parallax of 0°.14 is obtained, presumably due to absorption. Upon comparing the difference in longitude between the Gegenschein and the point op-

posite the Sun, with the position of the Gegenschein in longitude, no very satisfactory result was obtained but a suggestion remained that the difference becomes a maximum during the two separate intervals in which the Gegenschein can be observed, that is, from 150° to 240° and from 320° to 40° of longitude, and, judging from the means alone, each maximum has a slight minimum at its apex.

The Gegenschein is easy to observe from any locality not drowned in electric lights. It is only necessary to stand at some point from which the open sky is visible and pass the eyes backward and forward over the portion thought to be opposite the Sun, and pick out the brightest point. Aid is gained by putting the eyes out of focus so that the stars are not so distinctly seen, and then by pointing the finger at the selected spot one can keep the place until its position is well estimated with reference to surrounding bright stars; after that, tracing cloth stretched upon any good star map will give opportunity for drawing a permanent record from which the right ascension and declination may at any time be measured. At the same time the portion of the zodiacal band stretching across the sky may be observed. In these lines there is a splendid chance for any amateur with time and interest to discover something new.

LOWELL OBSERVATORY,
Flagstaff, June 29, 1897.

ASTRONOMICAL WORK AT LICK OBSERVATORY.

EDWARD S. HOLDEN *

FOR POPULAR ASTRONOMY.

In your letter of June 26 you ask for some account of the work in progress here for POPULAR ASTRONOMY, which I am very glad to give. A report of the sort is annually made to the Regents of the University of California and from the forthcoming report the following summary is made. It must be remembered that the work of this year is in continuation of previous work, and often in pursuance of plans laid down in 1874—23 years ago. While the resources of the Lick Observatory are large in comparison with those of many College Observatories they are very small in relation to those of the great establishments of Greenwich, Paris, Pulkova, Washington and Harvard College. For instance the

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whole available income of the Lick Observatory for the coming fiscal year (exclusive of salaries) is $5,145. This sum must keep all the buildings painted and in repair; keep all our reservoirs and some five miles of underground pipes in order; provide for all painting, plumbing, brick-laying, pipe-fitting, carpenter work, machine work, etc. etc., in the Observatory and in the houses of astronomers and workmen; buy all supplies such as lumber, hay, iron, brick, etc.; pay for all instrument-making not done in the Observatory; pay all freight, express and telegraph bills; maintain a telephone line 17 miles long in good order; pay for fuel; purchase books for the library; provide any needed apparatus for all the instruments; and, this year, buy much of the material needed for an eclipse expedition to India. It is no small task to make the small income cover the requirements. Every want which is felt in a large city is felt here. The circumstances at Mount Hamilton are as different as possible from those at Eastern Observatories. There each person must provide for his own personal comfort; here the comfort of each one must be secured by the expenditure of the annual appropriation. If it is insufficient every person suffers in some degree.

The astronomical efficiency of the Lick Observatory cannot be properly estimated without taking such material and social considerations into account Under the circumstances I do not think it is too much to claim that its efficiency during the nine years of its life has been satisfactory. This has only been attained by good will and earnest effort on the part of all concerned—regents, astronomers, mechanics, workmen. The summary of work for which you asked, is given below.

Double Stars have been measured here in past years in great numbers by Professor Burnham, and at the present time Professors Schaeberle, Hussey and Aitken are engaged in such work for parts of their time.

The Satellites of Mars, Jupiter, Uranus and Neptune have been regularly observed here for the past nine years by Messrs. Schaeberle, Barnard, Campbell and Hussey. A fifth satellite of Jupiter was discovered by Professor Barnard in 1892.

The Planets, especially Mars, Jupiter, Saturn (and also Venus and Uranus) have been systematically observed for their physical features at every opposition by Messrs. Holden, Schaeberle, Keeler, Barnard and Hussey. For several oppositions of Mars the planet has been followed by Messrs. Holden, Schaeberle and Campbell during every available hour.

Comets have been discovered here in great numbers. Ten com-

ets (seven unexpected) were discovered by Professor Barnard from 1888 to 1892; five (four unexpected) by Mr. Perrine from 1895 to date. The long series of observations of these and other comets by Messrs. Barnard, Campbell, Hussey, Perrine and Aitken are a contribution to science even more important than the discoveries themselves.

Comet-Orbits have been computed here by Messrs. Schaeberle, Campbell, Hussey, Perrine and Aitken; and all comets discovered at the Observatory have had their first orbits calculated by officers of the University. In this work Professor Leuschner, of Berkeley, a former student here, and his assistant, Mr. F. H. Seares, have rendered assistance which is much appreciated.

Meteors have been observed and photographed here (and elsewhere) by all the astronomers, and their orbits calculated by Messrs. Holden and Schaeberle.

Double-Star Orbits have also been computed by Professor Schaeberle.

The Zodiacal Light was regularly observed (visually) by Professor Barnard.

The Aurora has been regularly observed (spectroscopically) by Professor Campbell.

Typical or remarkable Cloud-forms are regularly photographed by Mr. Pauli, janitor of the Observatory.

Nebulæ have been observed (visually, photographically and spectroscopically) by Messrs. Holden, Burnham, Schaeberle, Barnard and Campbell.

Star maps have been made and published by Mr. Tucker.

Photometry: (photographic and visual)—of eclipses and of stars—has been attended to by Messrs. Holden, Schaeberle, Campbell and Leuschner.

Solar Eclipses: those of January and December 1889, April 1893, August 1896, have been observed by Messrs. Burnham, Schaeberle, Keeler, Barnard, Hill, Leuschner and Campbell—and the latter will observe the eclipse of January 1898 in India.

Lunar Eclipses.—All lunar eclipses visible here have been observed.

Occultations.—A series of occultations has been observed here by Professor Leuschner.

Transits of Mercury.—Three transits of Mercury have been observed (either visually or photographically).

Transit of Venus.—That of 1882 was successfully photographed here by Professor Todd.

Catalogues of Stars.—Two such are in progress of preparation.

1st. A catalogue of double-stars and of Coast Survey stars from observations by Professor Schaeberle has been (partly) reduced, on lines laid down by myself, by Messrs. Schaeberle, Campbell, Leuschner, Aitken and Professor Bigelow and Mrs. Updegraff. Professor Aitken has spent more than a year on this work.

2d. A catalogue of 38,000 stars from Washington observations is well towards completion. The reductions have been made chiefly by Messrs. Holden and Aitken. The original observations as printed were full of errors. The final places will be considerably more precise in declination and somewhat less precise in right ascension than the southern zones of Argelander.

Solar Photography.—Some 1,800 negatives of the Sun (taken with the photoheliograph) have been secured by Mr. Perrine and since April, 1896, some 450 more by Mr. Colton. Excellent experimental solar photographs on a large scale have been made with the 36-inch telescope and it is hoped to go very much further with this work during the summer of 1897.

Lunar Photography.—A very full series of focal negatives has been made with the 36-inch telescope chiefly by Messrs. Holden and Colton. An atlas on the scale of X-feet to the Moon's diameter has been prepared from these by Professor Weinek at Prague. Enlargements in the telescope have been made by Messrs. Holden, Colton and Perrine and 5 plates of a Moon atlas on the scale of III-feet to the Moon's diameter have already been distributed. Twelve more plates are now in the hands of the engraver and will soon be issued; and about 20 more are ready to be published when the funds are available. The atlas will be complete with about 60 plates. All the work in the dark room is done by Mr. Colton.

Photographs of the Milky Way.—A great number of such pictures has been obtained by Professor Barnard who is preparing them for publication.

Photographs of Planets (especially of Jupiter) have been regularly made by Messrs. Holden, Schaeberle and Colton.

Photographs of Comets have been secured by Messrs. Barnard, Hussey and Colton.

Visual Photometry.—Two fine photometers of Professor Pickering's design have lately been given to us by Miss Bruce. They will be used by Professor Aitken, chiefly on double-stars at present.

Spectroscopic observations of nebulæ, new stars, comets, stars and planets, have been made by Messrs. Keeler and Campbell.

The chief problem of the great telescope is to determine the motion of the solar system by spectroscopic observations. It was first attacked here in 1888 and since that time it has been considered as our most important work. The results now attained by Professor Campbell are of unexampled precision, and some of them will be published shortly. Many unexpected delays have occurred in this research which has been under the charge of Messrs. Keeler, Crew and Campbell.

Time-signals are sent out daily. Mr. Tucker is in charge of our clocks.

Meridian-Circle Observations.—Mr. Tucker has completed a fine series of observations of all stars contained in any of the great *Ephemerides* and *not* contained in the Berliner Jahrbuch. This work is all ready to print. He has also determined the places of a long list of stars used by Professor Doolittle to determine the latitude of Lehigh University. The division errors of the 1° spaces of both circles of the instrument have been determined by Mr. Tucker with the assistance of Mr. Aitken.

Meteorological Observations (tri-daily) have been regularly made. They are now in charge of Professor Aitken. A summary of all meteorological observations made here from 1888 to 1897 is in course of preparation by Mr. Perrine.

Earthquake Observations are obtained on our two Seismographs which are in charge of Mr. Perrine. A complete list of all recorded earthquakes on the Pacific Coast from 1769 to 1897 has just been prepared by Professor Holden.

Publications of the Observatory. The Observatory has already issued three quarto volumes and five octavos beside several pamphlets and the Moon-Atlas. The Smithsonian Institution has lately published an octavo prepared here by Professor Holden—Mountain Observatories—and will probably print his list of recorded earthquakes, just mentioned. Notices from the Lick Observatory regularly appear in the publications of the Astronomical Society of the Pacific. More than 1200 contributions to astronomical and other journals have been made by the officers of the Observatory since 1888.

Trial of the Crossley Reflector.—This fine instrument, which had done such good work in the hands of Mr. Common, was presented to the Lick Observatory by Mr. Crossley in 1895. It was completely mounted in June, 1896, and given over to Professor Hussey for trial. The work begun in 1896 is now being prosecuted. Photography in the Newtonian and principal foci will be tried by Professor Hussey, and Professor Campbell has a

programme of spectroscopic observations to be carried on with the Bruce spectrograph (constructed here) in the principal focus. A powerful driving-clock (the Bruce clock) has been made here from drawings by Professor Hussey. It is essentially a copy, in little, of the Warner & Swasey clock of the 36-inch equatorial. Its conical pendulum weighs about 56 pounds.

The Schaeberle 18-inch Reflector has been used for some years past in experiments in celestial photography by its maker, Professor Schaeberle. Very interesting photographs of Jupiter have been obtained.

The Crocker Photographic Telescopes (a pair of Willard portrait lenses) will soon be mounted in a new Dome near the Crossley Reflector. A 12-inch mirror (by Professor Schaeberle) of very short focus is to be mounted on the same stand.

Lick Observatory, July 7, 1897.

THE DEVIATION OF A FALLING BODY FROM THE VERTICAL.

H. C. WILSON

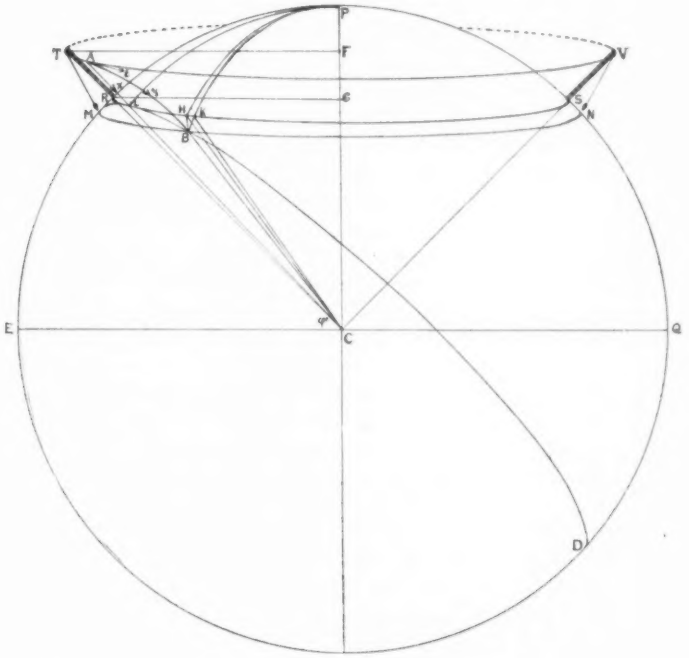
An interesting note appeared in one of the recent French periodicals,* in which the writer by a very natural error, showed that a body dropped from a great height would fall toward the south as well as east of the vertical. As the matter had never been presented clearly to my mind, I have put a little study upon it and have thought that a brief discussion of the subject might be of interest to the readers of POPULAR ASTRONOMY.

We all have in mind the simple truth that, according to the law of gravitation, the Earth attracts bodies towards its center. If the Earth were at rest a body let fall from a height above its surface or dropped into a hole, would fall straight towards its center. The Earth, however, is in motion; it moves through space and also rotates upon an axis. The movement through space, being common to all parts of the Earth, would not affect the relative movement of the parts, hence would not disturb the fall of a body toward the center. The movement of rotation, however, imparts unequal velocities, varying with the distance of the parts from the center. The top of a tower moves faster than the foot, and the bottom of the shaft of a mine slower than the

* *Bulletin de la societe astronomique de France.* Fevrier 1897.

mouth because of the longer and shorter radii of rotation. A ball held at the top of a tower acquires the velocity of the top of the tower and, when set free, tends to move with that velocity toward the east, as well as to fall toward the center of the Earth under the influence of gravity. Hence while falling it must gain in its easterly motion over the slower moving points below it, and so fall toward the east.

FIG. 1.



A reference to Fig. 1 may make this plainer. In the figure let the circle *PEDQ* represent the circumference of the Earth; let *TR* represent a high tower from which a ball is to be dropped. By the rotation of the Earth the tower is carried around a conical surface, the top describing the circle *TV* in 24 hours, while in the same time the foot of the tower describes the smaller circle *RS*. The velocities of eastward movement are proportional respectively to the radii of rotation *TF* and *RQ*, and these by similar triangles are proportional to *TC* and *RC*, the distances of the top

and foot of the tower from the Earth's center. It is clear thus that a ball dropped from T having an eastward velocity proportional to TC, and free to retain that velocity, must fall in advance of R, which has a velocity proportional only to RC.

Not only should the ball deviate toward the east but it should apparently fall to the south of the vertical. For, when it is set free, at any point as at A, it will no longer follow the curve TAV but will tend to fly off along the tangent At. Gravity will also tend to pull it along the line Ax. The resultant movement will be along Ay in the plane of the two lines At and Ax instead of in the conical surface. If disturbed by no other force, the ball must remain in this plane and hence must strike the Earth at some point B in the great circle LBD formed by the intersection of the plane with the spherical surface. While the ball falls from A to B the foot of the tower will be carried from L to H. The point B must clearly be to the south as well as east of H. Indeed we can imagine a tower so high, or a rotation so swift, that the ball would fall as far south as the equator or even fly off from the Earth altogether.

While this is true of the deviation of a falling body from the line joining it with the center of the Earth, it is not true when we speak of the deviation from the *vertical*. The error lies in confounding the vertical with the line extending from the Earth's center through the point of observation. The vertical is the direction assumed by the line of the plummet, when freely suspended and subject to no other influences than the Earth's attraction and rotation, or it is the *direction of the resultant of the force of gravity and the centrifugal force due to rotation.*

Let TM be a plummet suspended from the top of a tower. If the Earth were at rest the plummet would take the direction TR, but on account of the velocity of rotation the plumb-bob, being free to move, tends to go off on a tangent and hence swings out toward the equator, just as, when one whirls above his head a ball attached to the end of a string, the ball swings outward so as not to touch the body. This tendency of the parts of whirling bodies to fly off upon a tangent is called in mechanics the centrifugal force. In the case of a body like the Earth it may be resolved into two components, one of which acts to diminish the effect of gravity, the other to move the particle affected toward the equator. It is this force which causes the Earth to bulge at the equator and flatten at the poles, giving it the ellipsoidal form.

The plummet TM, then, which marks the direction of the vertical, points not toward the center but to a point below C, and its

lower extremity describes the circle *MN* in its rotation. Now the calculation shows that the deviation of the plumb-line toward the south is almost exactly equal to that of the falling body, so that, as measured from the vertical, there should be no perceptible deviation of the falling body toward the south. This is what has been found as the most probable result of experiment. The deviation toward the east is small, only about 1.5 inches for a fall of 500 feet. In our figure we have purposely exaggerated the displacements in order to render them visible.

The question is not a new one. In 1679 Newton proposed to prove the rotation of the Earth by measuring the eastward deviation of falling balls. Dr. Hooke, who was secretary of the Royal Society at the time Newton suggested this method, and who was renowned for his many mechanical contrivances, undertook to perform the necessary experiments. On January 14, 1680, he reported the results to the Society, stating that the height from which he dropped the balls was twenty-seven feet, and that they fell to the southeast. We know that there must have been some error in Dr. Hooke's work, for the deviation in a fall of 27 feet would be hardly one-fiftieth of an inch, which would scarcely be recognizable in the mass of inevitable errors of observation.

Mr. Henry Worms in 1862 gave a very complete account of the whole subject in his work "The Earth and its Mechanism," from which we take the most of the facts in this paper.

In 1791 Guglielmini, a geometer of Bologna, commenced making experiments in the tower degli Asinelli, which is 300 feet high. After many unsuccessful trials and various alterations in his apparatus, he gave up working in the daytime because he discovered that the traffic caused the tower to vibrate, and selected nights when the air was calm. The liberation of the balls was effected by burning the threads by which they were suspended, and this was never done until they had entirely ceased to oscillate, as observed by a microscope. The balls fell upon a cake of wax spread upon the ground, and the holes made by them nearly coincided, the greatest distance between two centers scarcely amounting to half a line ($\frac{1}{24}$ of an inch). The persevering philosopher finally dropped a plumb-line in August, 1791, but was obliged to wait until February 1792 before it came to a state of perfect rest. He then found the mean deviation of the sixteen balls he had dropped was 7.4 lines east and 5.27 lines south. These results were received by the scientific world with the greatest interest, when Lalande announced that Laplace's theory

gave only a deviation of five lines to the east and none to the south. This striking difference of theory and observation was at once explained by a trifling circumstance, overlooked in the otherwise most accurate experiments of Guglielmini, but the explanation overthrew at the same time all their force of demonstration. The difference was occasioned, first, by a local disturbance of the air, owing to the numerous perforations in the wall of the tower, and secondly, by a slight curvature of its structure. Also the balls were dropped in the summer, but the vertical was only ascertained six months afterward, in the winter, and there is no doubt the difference of temperature was sufficient to shift the point of suspension.

In 1802, Dr. Benzenberg commenced a series of experiments in St. Michael's tower in Hamburgh, which is 402 feet (French measure) in height and most suitable for the purpose, for an uninterrupted fall of 340 feet may be obtained, exceeding that in the Asinelli by ninety-nine feet and that in St. Paul's by eighty-five feet. But as only 240 feet of the tower, from the base upwards, were completely closed, Benzenberg chose a height of 235 feet for his investigations in order that even strong winds might not influence the results. The balls he used were 1.6 inches in diameter, and made of equal parts of lead and tin with the addition of a little zinc, an alloy which is easily turned and polished; they were tested by being placed upon quicksilver, and those which betrayed eccentricity in floating were rejected. The suspending thread was cut by a special device, for burning might have caused a slight draft and an oscillation of the ball before being detached. The cutting apparatus was reversed in the middle of the series lest it should have given some impulse to the balls. Such proves from the measures to have been the case, for the 16 balls dropped before reversal gave a mean deviation of 0.53 lines north and 2.6 east, while the 15 balls dropped after reversal gave a deviation of 3.53 lines south and 5.46 east. These experiments were made on eight days during the interval from July 23 to Oct. 26, 1802. We have quoted so much of detail concerning them in order that the reader might gain some idea of the delicacy of the experiment, and the difficulties attendant upon so apparently simple an act as that of dropping a ball truly.

Dr. Benzenberg repeated his experiments in 1804, using an abandoned coal-pit at Schlebusch in the county of Mark, Westphalia, situated in latitude 51° 25′, and about 264 feet deep, of which 262 feet were available for the free descent of the balls. Twenty-nine trials on three days gave a northerly deviation of

0.7 lines and easterly 5.1 lines. Theory gives for the easterly deviation 4.6 lines, which is in very satisfactory agreement with the observation.

A long series of similar experiments were made in 1831 by Professor Reich in the mines of Freiberg in latitude 50° 53′ 23″ north. The depth he could command was 488 feet, nearly double that used by Dr. Benzenberg. He made 106 trials and the mean results gave only a slight southerly deviation, less than half a line. and an easterly deviation of 10.32 lines, a little less than that required by theory.

The derivation of the mathematical equations connected with the subject it is not easy to put into popular or even simple form, yet there may be some of our readers who will wish to go through what is given in the following paragraphs.

To find the easterly deviation, let the tangential velocity at L in Fig. 1 be represented by v_1 and that at A by v_2. The gain of A over L in eastward motion in the unit of time will be $v_2 - v_1$, and in t seconds will be $(v_2 - v_1)t$. If we represent the Earth's radius LC by r and the height AL by h then

$$v_2 : v_1 :: r + h : r$$

and

$$v_2 - v_1 : v_1 :: h : r$$

$$\therefore \quad v_2 - v_1 = v_1 \frac{h}{r}. \tag{1}$$

Now since the Earth rotates in a siderial day, the tangential velocity per second at any point must be the circumference of the circle of latitude of that place divided by 86164, the number of solar seconds in a sidereal day. Hence

$$v_1 = \frac{2\pi \times (RG)}{86164} = \frac{2\pi r \cos \varphi'}{86164}. \tag{2}$$

If d represent the eastward deviation of the falling ball, we shall then have from (1) and (2)

$$d = (v_2 - v_1)t = \frac{v_1 th}{r} = \frac{2\pi th \cos \varphi'}{86164}. \tag{3}$$

This would be true if the balls were to be dropped in a vacuum and if the direction of gravity were to remain parallel to itself during the time of falling, but neither of these conditions can be fulfilled in the actual experiment. Calculations which we cannot give here, show that the change in direction of gravity would diminish the deviation about one third, and that a slight diminution would also result from the resistance of the air, so that the final formula given by Worms is

$$d = \frac{4\pi t \left(h - \frac{1}{2}\Delta\right) \cos \varphi'}{3 \times 86164}, \tag{5}$$

in which Δ denotes the excess of descent in vacuo above that in air. In the Benzenberg experiments Δ amounted to about 9 feet and in those by Professor Reich about 57 feet.

To obtain the formula for the southerly deviation we may solve the spherical triangle PLB, in which we wish to determine the difference between PL and PB. The side LB is equal to eastward movement of the top of the tower in the time of falling t, and calling this ε we shall have

$$\varepsilon = \frac{2\pi t}{86164} \cdot \frac{r+h}{r} \cdot \cos \varphi', \tag{6}$$

in which for this calculation we may call $\frac{r+h}{r} = 1$. The side PL is the complement of the geocentric latitude, the angle L is a right angle and PB is the complement of the latitude of the point where the ball falls which we will call φ. Then by Napier's rule we have

$$\sin \varphi = \sin \varphi' \cos \varepsilon = \sin \varphi' \left(1 - 2 \sin^2 \frac{1}{2} \varepsilon\right), \tag{7}$$

$$\sin \varphi' - \sin \varphi = 2 \sin \varphi' \sin^2 \frac{1}{2} \varepsilon. \tag{8}$$

$$2 \sin \frac{1}{2} (\varphi' - \varphi) \cos \frac{1}{2} (\varphi' + \varphi) = 2 \sin \varphi' \sin^2 \frac{1}{2} \varepsilon, \tag{9}$$

Now since the time of falling, in the practical experiments, is only a few seconds, the arcs $\varphi' - \varphi$ and ε are very small and we may without appreciable error write the arcs for their sines. and $\cos \frac{1}{2} (\varphi' + \varphi)$ will be equal to $\cos \varphi'$. Making these substitutions, equation (9) becomes

$$(\varphi' - \varphi) \cos \varphi' = \frac{\varepsilon^2 \sin \varphi'}{2}. \tag{10}$$

Dividing by $\cos \varphi'$ and substituting the value of ε from (6) we obtain

$$\varphi' - \varphi = \frac{2\pi^2 t^2 \sin \varphi' \cos \varphi'}{(86\,164)^2}. \tag{11}$$

Multiplying by the radius to reduce this to linear measure, we have for the southerly deviation from the line extending to the center of the Earth

$$\delta = \frac{2\pi^2 t^2 r \sin \varphi' \cos \varphi'}{(86\,164)^2}, \tag{12}$$

or if we substitute for t^2 its equivalent $\frac{2h}{g}$, we shall have

$$\delta = \frac{4\pi^2 hr \sin \varphi' \cos \varphi'}{g\,(86\,164)^2}, \qquad (13)$$

in which g is the velocity imparted by gravity in one second, 32.16 ft.

To determine the deviation of the plumb-line from a line toward the Earth's center, we will begin with the formula for centrifugal force in mechanics

$$f = \frac{v^2}{r}, \qquad (14)$$

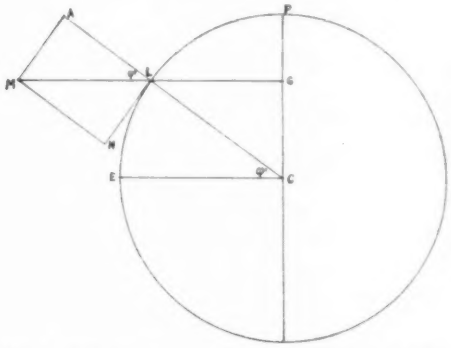
where v is the velocity of a body moving in a circle, r is the radius of the circle and f is the centrifugal force, and since the velocity equals the circumference of the circle divided by the time of a revolution, if we take 1 second as the unit of time,

$$v = \frac{2\pi r}{86\,164}$$

and

$$f = \frac{4\pi^2 r}{(86\,164)^2}. \qquad (15)$$

FIG. 2.



This is the expression for the centrifugal force at the Earth's equator. At any other point on the Earth's surface, as at L, the centrifugal force will be less in proportion to the radius LG of rotation. In Figure 2 let LM, drawn equal to LG, represent the centrifugal force. This may be resolved into the two components, represented by LA and LN, the one opposing the force of gravity, the other urging the particles at L toward the equator. But

$$ML = LG = r \cos \varphi'$$

and

$$LN = ML \sin \varphi' = r \sin \varphi' \cos \varphi'.$$

Hence the force which urges the plummet to the south is, by substituting LN for r in (15),

$$f_s = \frac{4\pi^2 r \sin \varphi' \cos \varphi'}{(86\,164)^2}. \qquad (16)$$

This force will move the plummet until its effect is balanced by

the horizontal component of the reaction of the suspending string, or in other words the horizontal component of the force of gravity upon the deviating plummet. This will be when

$$\delta' : h :: f_n : g,$$

hence
$$\delta' = \frac{hf_n}{g} = \frac{4\pi^2 hr \sin \varphi' \cos \varphi'}{g\,(86\,164)^2}. \qquad (17)$$

which is identical with equation (13) which we found for the deviation of the falling body toward the south.

In deriving some of these equations we have neglected certain small quantities, because their effect upon the results would be inappreciable. A more rigorous calculation shows that there is a difference between δ and δ', but that it is too small to be determined by experiment. In the June 1897 number of the *Bulletin de la société astronomique de France* M. Maurice Fouché gives for the actual deviation of the falling body south from the vertical

$$\delta - \delta' = \frac{8\,\pi^2 h^2 \sin \varphi' \cos \varphi'}{3\,g\,(86\,164)^2}. \qquad (18)$$

If we calculate (18) for latitude 45°, where $\delta - \delta'$ is at a maximum, and $h = 500$ ft., since $\pi = 3.1416$ and $g = 32.16$, we shall obtain for the southerly deviation

$$\delta - \delta' = \frac{8\,.\,(3.1416)^2\,(500)^2\,.\,\frac{\sqrt{2}}{2}\,.\,\frac{\sqrt{2}}{2}}{3\,(32.16)\,(86\,164)^2} = 0.0002 \text{ inches},$$

a quantity wholly inappreciable compared with the probable errors of the measures.

The computation of equation (5) gives, with the same data, the easterly deviation

$$d = 1.4 \text{ inches},$$

and (13) gives for the deviation of the plummet toward the south

$$\delta = 2.1 \text{ inches}.$$

THE AIMS OF STELLAR ASTRONOMY.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

What is the aim of Stellar Astronomy and what may be expected of the study of the double and multiple stars? is a question frequently asked by intelligent persons and even by profes-

sional astronomers occupied with other lines of research. To set forth briefly some of the aims of this branch of the Science, and to point out some of the results made known by the labors of astronomers during the past century, is the purpose of this paper.

In general, Stellar Astronomy can lay no claim to superiority over other lines of exact Science, such as Mathematics and Physics, but as Lord Kelvin expresses it*:—

"Double Star Astronomy has always been exceedingly interesting in giving us some fundamental information of systems in different parts of the Universe, analogous to our solar system in respect to orbital motion under gravitational force, but different from ours in that grand detail of two Suns instead of one. And the interest is now greatly enhanced by revelations of physical properties and of velocities relatively to our system which spectrum analyses have given us within the last 33 years. I enclose an extract† from a letter which I received from Tisserand only a few months before his death, by which you will judge how eagerly I looked to your chapter 3‡, § 4, and how much interested I was to find in it the italicised paragraph on page 251. The physical cause of the great eccentricities of the orbits of double stars is certainly a very important subject for investigation or speculation."

The consideration that our Solar system is only one among thousands of systems now known to exist in every part of the heavens, and that among all these other systems there is not yet disclosed a single one which closely resembles our own, ought to be sufficient to assure us of the dignity and importance of Stellar Astronomy.

From our present knowledge it is not possible to say that Systems like our own do not exist, but merely that we have no knowledge of them, and that such knowledge seems likely to be delayed for many years. For with our present means of measurement very minute perturbations among the fixed stars can not be detected, and bodies like the planets have masses too small to produce sensible perturbations in the place of a star about which they might revolve. Moreover such small obscure bodies would be wholly invisible in all existing telescopes; and even if telescopes one hundred times more powerful should be built, these

* Letter to the writer.

† Relative to the eccentricities of double star orbits as made known by the writer in a paper read before the National Academy of Sciences at the Washington meeting, April 22, 1896, and printed in the *Astronomical Journal*, No. 378.

‡ Researches on the Evolutions of the Stellar Systems, Vol. I.

also would be equally incapable of showing non-luminous bodies as small as Jupiter attending the fixed stars.

We may condense the principal aims of Stellar Astronomy under the following heads:

(*a.*) *The Comparison of Other Systems with Our Own.*—Observations and researches of the past century show that among known systems we hold a unique place. The planetary system is very complex, and its numerous small bodies all move in very circular orbits about large central masses, while the Stellar systems are characterized by a very few equal or comparable masses and by very eccentric orbits. On the other hand the same law of Newtonian gravitation which regulates the motions of dark, cold, solid bodies like the Earth and Moon and the Satellites of Jupiter, governs also the self-luminous stars in their orbits, and we may thus see the universality of the Newtonian law exemplified among bodies of the most diverse conditions and temperatures in the most remote regions of space. It is important to investigate any and all causes which may appear to disturb the operation of this law. The most natural explanation of perturbations of the elliptical motion is the action of other bodies, and when such irregularities are shown to exist, as in the systems of ζ Cancri and 70 Ophiuchi, we should seek to locate the bodies from which they arise, keeping in mind, however, other foreign causes which might explain the phenomena. The aim of observations is to render all orbits more and more exact, and hence in time it will become necessary to explain small differences and anomalies which in the early stage of the science could be disregarded or attributed to errors of observation. In this way we may suppose that some day discoveries as interesting if not as striking as that of Neptune will be made among the fixed stars.

(*b.*) *The Determination of a Large Number of Stellar Orbits With a View of Throwing Light Upon the Law of the Eccentricity Recently Discovered.*—Since our system is throughout characterized by such circular orbits, every system with an orbit of a radically different character offers the highest interest with respect to the cosmical agencies which have produced such different results. It will thus become important to investigate accurately several hundred orbits with a view to assigning the cause of the elongation of the stellar orbits. In this connection it may be pointed out that the eccentricity is the element of highest interest, not the period as has been carelessly assumed by many. For the period will give us nothing of real interest unless the parallax

is known, in which case we obtain the mass and absolute dimensions of the system; on the other hand the eccentricity is determinable in every revolving system without regard to parallax, and immediately reveals the true nature of the system—the variation in the distance of the companion during a revolution, and the resulting tidal action or perturbation that may arise either in the masses of the stars, or in the motions of other bodies attached to the system. Besides, the confirmation of the general law of the eccentricity will throw light upon the processes by which the systems have formed, and thus enable us to determine whether in some cases exceptional causes have been at work. It is also not unlikely that the tidal perturbation arising from the great eccentricity of the orbit will be found to occasion variability in the components of stellar systems. The critical investigation of these phenomena will some time become an important subject of scientific inquiry.

(*c.*) *Determination of the Absolute Dimensions of Systems by the Visual and the Spectroscopic Methods.*—Both methods of parallax measurement are very difficult, but by determining a large number of orbits it is practically certain that quite a number of systems will supply the desired information as to their distances, and yield results of the highest interest to exact astronomy. No element now made use of in astronomical research is in a more unsatisfactory state than stellar parallax, and hence knowledge that will enable us to improve its determination will be a most welcome contribution to science. If the velocities of the stars in their orbits be sufficient to admit of the application of the spectroscopic method, the line of research thus opened up will yield the dimensions not only of systems which are near us, but also of those which are at the most remote distances—of perhaps a thousand light years—where the parallax by any and every other method would always be hopelessly beyond the limit of measurement.

(*d.*) *The Determination of the Relative Masses in Stellar Systems.*—During the past century a number of binary stars have made whole revolutions, and hence if suitable measures had been secured of the places of either component with respect to some neighboring star, it would now be possible to find the location of the centre of gravity, and thus deduce the relative masses of the two stars. Such investigations have been made heretofore in three systems only, viz: α Centauri, Sirius, and η Cassiopeiæ, and in each case the result has been based upon positions given by the meridian circle. The method recently proposed, analogous to

that employed in the measurement of parallax, is very much more exact, and ought to be applied to every known binary system which has suitable comparison stars.

In about another half century many important researches of this kind can be effected, and the early measures will then possess the highest interest. These investigations of the centres of gravity of stellar systems are required for the Catalogues of precision, as well as in the theories of Cosmogony; for since the centre of gravity alone moves uniformly on the arc of a great circle, this must be determined before the proper motion can be deduced with accuracy, or the places of either component given in the Catalogues of precision.

(e.) *The Law of Color among Double Stars and its Relation to the Relative Ages of the Components.*—It is already known that in general the color of the companion lies nearer the blue end of the spectrum than that of the principal star. Is this law general, and if so, what is its physical cause? If the law is not general, how and under what circumstances do exceptions arise?

It is assumed by spectroscopists that the blue stars are in an early stage of development, surrounded by an enormous envelope of hydrogen at a great temperature; and that red stars are relatively old, and already surrounded by atmospheres containing numerous hydrocarbon compounds. Is this hypothesis reconcilable with the colors among double stars where the components have the same absolute age? It must be assumed, other things being equal, that smaller masses, according to known laws of cooling, would condense more rapidly than larger ones, and hence it does not appear why the companion stars should be in the earlier stage of development. The supposition that the large star is the more advanced in development is also directly contradicted by the analogous phenomena observed in the solar system, where the Sun is still self-luminous, while Jupiter and Saturn are hot masses of gas, and the small bodies like the satellites and smaller planets (including the Earth) are already crusted over by cooling, and almost, if not quite, solid. Some evidence exists that the companion would lose its more volatile gases by the attraction of the larger star, but this thinning of its gaseous envelope ought not to retard but rather to accelerate its development. The analogous result has happened in the case of our Moon and Jupiter's satellites, which are already cosmically dead, while their planets are still in an early stage of their life history. It is therefore to be settled by future research whether the spectroscopic theories are really correct, and for this reason both spectroscopic

and color studies of the individual components of stellar systems are greatly to be desired.

(*t.*) *The Study of Multiple Stars will Lead to an Improvement in the Theory of Perturbations.*—It was Lagrange who remarked that, if nature had not given us such a singular arrangement of the planets and satellites we could never have determined their mutual perturbations by the methods of modern analysis. This singular arrangement consists in the common direction of motion, the great mutual distances of the planets, and their small masses compared to the Sun's mass, whereby their mutual action is very small. As the orbits lie nearly in the same plane, and are also very nearly circular, the mutual action of the planets never becomes very large compared to the principal forces by which they are governed.

The same arrangement is observed among the satellites as among the planets; and as the satellites are relatively near the planets, their motions are not greatly troubled by the mutual action of the planets. In a Stellar system like ζ Cancri we have three large bodies, and the central system is greatly perturbed by the action of the third star. The same effect with greater extremes will hold true in systems like 70 Ophiuchi, where the eccentricity is higher, and the inclination may surpass the bounds familiar to Lagrange and Laplace. We shall eventually need a theory of perturbations much more general than that developed for the moon and the planets; the study of the Stellar systems will encourage and necessitate this development in the theory of attraction, but it may require a good many years to bring it about. The final theory of perturbations must take account of large disturbing forces, with orbits of great eccentricity and high inclination.

In closing these remarks we may again point out the close connection between theoretical and practical astronomy. Some persons with little insight into the real purpose and philosophy of science seem to reach their highest delight in speaking slightingly of "theories," whereas every student of nature recognizes that theories are not only convenient but necessary to enable the human mind to properly co-ordinate phenomena. It is sufficient to say that it is only by optical theories that telescopes were first conceived and finally perfected; that it is only by intelligent theory that the labors of the practical astronomer can be intelligently and usefully employed; and that without theory there is no causal connection of isolated phenomena and physical science could not exist. Without the theory of gravitation astronomy

would still be in the chaotic state which marked the period of Tycho, before the foundations had been laid by Kepler and Newton. A real science requires both carefully ascertained facts, accumulated in abundance, and intelligent theoretical discussion which will disclose the physical laws by which the phenomena are regulated. On the one hand observation improves and checks the deductions of theory, and on the other theory aids and simplifies the work of observation, by indicating to the astronomer what is essential and what is not essential, and thus dividing the wheat from the chaff.

Stellar astronomy, like other branches of science, is subject to these laws; and it is a matter of profound regret that some observers have so little insight into the real purpose of theory, and that some theorists are so unfamiliar with phenomena actually observed in the heavens, that the really great discoveries are made only by the few geniuses who have a wider grasp of the problems of science.

The future of stellar astronomy requires the cultivation of theory as well as of observation, and its best development is one that will yield not only facts observed in the sky, but also the causes from which we may build up a real philosophy of the universe.

Lowell Observatory,
Flagstaff, Arizona, 1897 July 6.

A COMPARISON OF THE PHOTOGRAPHIC AND OF THE HAND AND EYE METHODS OF DELINEATING THE SURFACE MARKINGS OF CELESTIAL OBJECTS.

F. L. O. WADSWORTH.

For Popular Astronomy.

The altercations which are at present going on between a number of observers in regard to the planetary markings, with respect first to their existence or non-existence, and second with respect to their movements and the consequent periods of rotation of the planet upon which they are seen or said to be seen, will serve at least one very useful purpose,—that of calling attention to the great unreliability of hand drawings, even when made by those at once experienced in observation and skillful in delineation. This unreliability has been conclusively demonstrated in the case of nebulæ by comparing the old drawings with the many photographs of the same objects which have been taken during

recent years. It is true that these last differ in some degree among themselves, but only to the extent that may be attributed either 1st, to legitimate differences in appearance produced by varying degrees of contrast between the nebula and the sky, or between the nebula and surrounding stars; differences due, other circumstances being the same, to differences in the linear and angular apertures respectively of the photographic lens used. (See article by writer in *Knowledge*, August 1897, and *Monthly Notices*, No. 9, 1897): or 2nd, to variations in the time of exposure and the method of development. (See articles by Max Wolf, *Nature*, April 22, p. 582, and Naegamvala, *Nature*, June 17, p. 153).

But these differences, aside from being so well accounted for by physical and instrumental variations (which may be controlled) are so small as compared with the disagreements and discrepancies in different *drawings* of the same object, that the superiority of the photographic method of delineation would seem to be unquestionable on practical as it is on theoretical grounds. And comparing the two processes point by point the photographic one is indeed found to be not only physiologically and psychologically, but also optically superior. For, 1st, given two objectives of equal size and quality, one photographically, the other visually corrected, the former will have in the first place a considerably greater resolving power (about 25 per cent. greater) for this is measured by the ratio of the linear aperture to the mean wave-length of the light brought to minimum focus:* 2nd, The photographic plate is, according to the experiments of Sir William Huggins, more sensitive to small differences in intensity than the eye, consequently fainter *contrasts* can be recorded photographically than can be seen directly:† and 3rd, The photographic plate will in virtue of its integrating effect, record details that are entirely invisible to the eye, which possesses no such power of summation: and lastly, whatever may be the anomalies of the photographic plate produced by over-exposure, over-development, etc., etc.,

* To photographically utilize the full resolving power of the objective we must have, on account of the finite size of silver grains in the plate, a certain minimum ratio of aperture to focal length defined by the relation $b/f = m\lambda/e$ where b and f are respectively the linear apertures and focal length of the objective, e is the mean size of the silver grains in the plate, λ the mean wave-length of the photographically active light, (which is or should be the same as the mean wave-length for minimum focus) and m a constant which for a circular aperture is not less than 0.25. See papers by the writer, "Notes on Astronomical Spectroscopes," *Astrophysical Journal*, Vol. III p. 176, 1896; and "On the Conditions of Maximum Efficiency in the Use of the Spectrograph," *Ibid*, Vol. III, p. 321, May 1896.

† Bakerian Lecture, "On the Corona of the Sun," Proc. Roy. Soc., Vol. 39, p. 108, 1884.

they are as nothing compared with the difficulties which beset even the most skillful artist when he attempts to *accurately*, (as distinguished from *artistically*) reproduce, even in black and white, what he sees. So far as questions of *contrast* between the sky and the object or between the latter and the stars, are concerned, the conditions are the same (apertures being equal) in the two instruments (photographic and visual).*

In view of all these facts it is surprising that there are still some who refuse to accept the evidence, both theoretical and experimental, against the eye and hand method, but prefer to rely upon results achieved in that way rather than upon those secured by photography. It was only in the last number of one of our leading astronomical journals, for example, that a certain observer, who shall be nameless, declares that a certain nebula in no way resembles the photographs that have been made of it (by an astronomer, by the way, whose work is not often questioned), and announces his intention of making an 'authoritative' *hand drawing* of the object, designed to serve doubtless as a standard of reference for future generations.

This is quoted not for the purpose of singling out any individual case, but as representing a very recently expressed opinion, more or less representative of similar opinions I have before heard expressed by some other observers. It seems to the writer that it is time that these prejudiced and erroneous ideas were banished from the minds of astronomers, and that those observers who are spending or proposing to spend their time and energy in making pictorial representations of celestial objects, particularly such objects as nebulæ, would see that they are doing little more, so far as they themselves are concerned, than accumulating a plentiful store of material for future controversy and dispute with others likewise engaged; while they prevent the employment of the instrument they are using in more fertile and useful fields of investigation. In the case of our large telescopes, of which we have by no means too many, this last is by far the most serious objection to this form of astronomical amusement.

In connection with the differences which appear between the best and most reliable drawings and the best photographs, it is of importance to recall the fact that there are in many cases real differences in the visual and the photographic images, on account

* See papers "On the Limiting Time of Exposure of Photographic Plates in Astronomical Photography," *Knowledge*, August 1897. "On the Effect of the General Illumination of the Sky on the Brightness of the Field at the Focus of a Telescope," *M. N.*, No. 9, 1897; and "On the Conditions of Maximum Efficiency in Astrophotographic Work," *Astrophysical Journal*, Aug., 1897.

of the varying distribution of intensity in the spectrum from different parts of the surface under examination. In the case of self luminous surfaces, such as the nebulæ,* the solar corona and prominences, and to a less degree the solar surface itself, these differences in the constitution of the light sent out by different parts may be due (1) to differences in chemical constitution; (2) to differences in temperature; in the case of surfaces shining by reflected light, such as the Moon and planetary surfaces, they are due to varying absorptive and reflective powers of different parts of the surface. Thus the forms of the solar prominences, as seen visually in the red hydrogen line, through the widened slit of a spectroscope, will often vary greatly, particularly in the case of eruptive prominences, from the forms as photographed with the spectroheliograph in the (violet) light of the K (calcium) line. Again the case of the Orion nebula there is a distinct change of color in one part of the great nebula, there being a long reddish purple streak running along the southern edge of the part in which the trapezium is located.† Marked differences in the intensities of the nebular lines in different parts of this object have also been observed by Professors Campbell‡ and Keeler.§

These differences in relative spectral intensity may even be sufficient in some cases to produce an actual difference in the visual appearance of the same object to different observers whose eyes differ in relative sensitiveness to different kinds of light. These physiological differences are larger than is sometimes supposed. In a recent experiment in determining the position of the focal plane of the 40-inch Yerkes telescope it was found that with a low power negative eyepiece, the point of most distinct focus varied by nearly two inches for different observers, Professor Barnard's focus being about an inch and a half further out than the

* Note added July 18th. Since this paper was written I have found that this cause of difference between photographs and hand drawings of nebulæ has already been pointed out by Professor Keeler, "On a Cause of Difference between Drawings and Photographs of Nebulæ," *Pub. A. Soc. Pac.*, Vol. VII, p. 279.

† This was first called attention to by Professor Barnard (*Knowledge*, May, 1894, p. 97.) It was discovered independently by Professor Hale, Mr. Ritchey and the writer while working with Mr. Ritchey's 24-inch reflector, which has recently been mounted at the Observatory. It has been held by some that this was an effect of chromatic aberration; by others that it was one of contrast. It cannot be due to the first, because Professor Barnard saw it in the 12-inch and the 36-inch refractors at Lick, while we saw it with a reflector. It does not seem to the writer that it can be due to contrast (or a complementary color effect) because according to Professor Barnard it is equally distinct with both high and low powers, and because it is seen only on *one* particular edge or part of this nebulous mass, and not on all sides of it.

‡ See paper by Professor Campbell "on the Spectrum of the Great Nebula in Orion," *Astronomy and Astro-Physics*, May, 1894, p. 384.

§ *Astronomy and Astro-Physics*, June 1894.

point of most distinct focus for Professor Hale, and about two inches further out than that for the writer. Professor Barnard's eyes, (like Professor Burnham's, whose focus Professor Barnard states is nearly the same as his own) would therefore seem to be most sensitive to the green and blue light, while those of Professor Hale and the writer are more sensitive to the greenish yellow and yellow rays. The retinal sensitiveness of the first two observers to light of the shorter wave-length is perhaps one reason for their wonderful ability as observers of close double stars. For them the resolving power of a telescope is really considerably greater than it is for the majority of observers whose maximum of retinal sensitiveness lies in the yellowish green.

In case of refracting telescopes there is a further difference in the appearance between the photographic and the visual image on account of the difference in the chromatic aberration of the two instruments. A visually corrected objective casts a general halo of bluish and violet light over the object; with a photographically corrected one, on the other hand, the diffused light is of longer wave-length (yellow and red). In this respect again the photographic plate has a decided advantage over the eye, because it is less affected by the outstanding light of long wave-length than the eye is by the outstanding blue and violet light in the field.

This question of the change in the appearance of the image of a body with a change in wave-length of the light in which it is viewed (visually or photographically) has, however, really nothing to do with the question of the relative advantage of the photographic and visual methods of delineation. If for any reason the image formed by the longer wave-length is in a given case a more useful representation of the body than the one formed by an ordinary photographic objective, there is nothing to prevent our still employing the photographic process of delineation, using orthochromatic plates instead of the ordinary bromide of silver plates, and a visually corrected refractor (or reflector) provided with color screens (placed near the focus) to cut out the light of shorter wave-length, instead of photographic objective. Photographs of some of the brighter nebulæ taken in this way would be most interesting and valuable for comparison with those taken in the usual manner.*

There is only one point of advantage which under the practical conditions of observation the eye possesses over the photographic film. The latter must necessarily take account of all the light which falls upon it, and the final photograph is the re-

* This has also been previously suggested by Keeler. See foot note on p. 203.

sultant effect of many successive impressions which may differ a good deal at different times owing to atmospheric disturbances. The result is very much the same (though produced by somewhat different causes) as would be produced by printing on silver paper from a negative placed film side upward or held at a considerable distance above the paper, or (what corresponds still more closely to the usual conditions) kept in continual vibration during the printing process. On the other hand the eye employs no such process of summation, but *makes the most of the intervals of good seeing*, being little influenced in forming the mental picture either by slight movements of the image as a whole or by occasional intervals of haziness and "fuzziness" due to momentary atmospheric or instrumental disturbances. This is probably the reason why eye observations have in certain cases, notably the case of the planets, given us greater detail than we have as yet succeeded in photographing. But this is not in itself decisive of eye observations; it simply indicates that the methods we have been following heretofore in photographing these objects is not the one calculated to secure the best results. I believe that with proper instruments and proper methods it will be possible to realize all the theoretical advantages of the photographic method of delineation in the case of planetary surfaces, (up to a certain size of aperture not greater perhaps than 12 to 15 inches), as they have already been in the case of nebular photography, and to a large extent in lunar and solar photography. There seems to be no good reason why we should not under proper conditions photograph all or even more (on account of greater resolving power and greater light action) than we can ever be sure we really see on a planetary surface. The problem is one deserving our most careful attention, and I have spent a good deal of time and thought upon it. Some time last winter a simple method of avoiding what seems to be the main cause of difficulty, *i. e.*, unsteadiness of image during exposure, suggested itself to me, and since then some experiments have been made by this method in photographing the solar surface with very satisfactory results. Up to the present time the unfinished condition of the Observatory and lack of proper instrumental facilities, has rendered it impossible to make any experiments in photographing the planets, but I hope to soon take it up. But in the hopes that I may induce someone else who has the proper facilities to give the proposed method a trial at once, (Venus is now favorably situated for this work) I have decided that it might be well to publish a description of it and of what has thus

far seemed to me (further experiments may induce me to change my ideas) the best instrumental equipment for carrying it out.*

Conclusion.—In this paper I have considered the relative advantages of the photographic and of the hand and eye method, only as regards accuracy of delineation. The case of nebulæ has been cited particularly not because those are the objects for which accuracy of delineation is most needed, but because it is with reference to them that the competency of the photographic method has recently been called in question. Its advantages on the score of accuracy are, however, even more strikingly illustrated by its use in studying solar, terrestrial and stellar spectra (the spectrograph has now practically superseded the spectroscope in nearly every field of astrophysical research)† and in determining parallax,‡ right ascensions,§ and variations of latitude‖; uses to which it has only recently been applied, but in which it has already proved its value.

The advantages of photography as regards rapidity, recording simultaneously as it does, the detail in a field sometimes 10° to 15° square (photographic doublets) while the eye is not able to take in the details over a region larger than a few minutes at the most, are so apparent and unquestioned as to require no comment. These advantages alone are of course sufficient to determine its use in studying all those phenomena which are of a transitory nature, or whenever for any other reason the time of observation is limited, as in the case of eclipses, transits, occultations, etc., etc. It is these advantages again that enable us to accomplish such a great amount of work as is represented in Pickering's general spectroscopic surveys, or in the International Astrophotographic survey, with a minimum expenditure of time, labor and instrumental equipment.

YERKES OBSERVATORY,
June 30, 1897.

* This paper will probably be published in the next (September) number of the *Observatory*.

† See the papers of Huggins, Rowland, Vogel, Keeler, Hale, Crew, Campbell, Kayser and Runge, Eder and Valenta, Hasselberg, etc., etc.

‡ See papers by Pritchard (*Monthly Notices, R. A. S.*, 1886 et. seq.), particularly "Researches in Stellar Photography; Its Applicability to Astronomical Measurements of Precision," Proc. Roy. Soc., Vol. 41, p. 195, 1886.

§ See papers by Pickering and Gerrish, Fargis, Hagen, Bigelow, Turner, Russell, etc. (*Proc American Academy, Astronomy and Astro-Physics, Publications Georgetown College Observatory, Monthly Notices, R. A. S.*, etc., etc).

‖ See papers by Fargis, Hagen, Marcuse, etc. (*Publications Georgetown College Observatory, Beob. der Kgl. Sternwarte zu Berlin*, etc).

THE HEAVENS FOR AUGUST.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

The Great Bear, (*Ursa Major*) is in the northwest, his paws near the horizon. Between the point overhead and the northern horizon, are the constellations of the Dragon (*Draco*) and the Little Bear (*Ursa Minor*). Between the north and northeast are Cepheus, Cassiopeia, Perseus, and Camelopard, whilst Andromeda is rising due northeast, her head marked by the star Alpha (*Alpheratz*). On the eastern horizon is the Winged Horse, Pegasus, and between it and the point overhead, is to be seen the Swan (*Cygnus*) and the Harp (*Lyra*), with its leading brilliant Vega. A little east of due south, we find the Archer (*Sagittarius*); in the southeast, low down, the Sea Goat (*Capricornus*); and farther east and lower down, the Water Bearer (*Aquarius*). Above the Sea Goat is the Eagle (*Aquila*) with its blue-white star Altair, and on its left the pretty little Dolphin (*Delphinus*). Low down near the south, we find the Scorpion (*Scorpio*) and the Wolf (*Lupus*). In the southwest are the Scales (*Libra*) and above the Scorpion and the Scales are the Serpent (*Serpens*) and Serpent-Bearer (*Ophiuchus*). Low down, extending from the western horizon nearly to the southwest is the Virgin (*Virgo*) with the bright Spica near its setting place. The Herdsman (*Bootes*) occupies the mid-heaven in the west, the Crown (*Corona Borealis*) higher up, and due west, Hercules being between the Crown and the point overhead.

These are the positions of the constellations on August 7th at 9 o'clock, August 14th at 8½ o'clock and August 22nd at 8 o'clock.

CONSTELLATION OF SAGITTARIUS.

The ruling constellation of the zodiac, during the month of August, is Sagittarius, the Archer. He is usually represented as a centaur, though it is not easy to imagine the figure of a centaur among the stars of this constellation. The bow, however, is fairly well marked. The constellation occupies a considerable space in the southern hemisphere, and contains 339 stars, including five of the third magnitude, and ten of the fourth.

It can easily be distinguished by means of five stars of the 3d and 4th magnitudes, forming a figure resembling a little short, straight-handled Dipper, turned upside down, with the handle to the west, familiarly called the *Milk Dipper*, because it is partly in the Milky Way. This little figure is so conspicuous that it cannot easily be mistaken. It is situated about 33° east of Antares, and comes to the meridian a few minutes after Lyra, on the 17th of August. Of the four stars forming the bowl of the Dipper, the two upper ones are only 3° apart, and the lower ones 5°. The two smaller stars forming the handle, and extending westwardly about 4½° and the easternmost one in the bowl of the Dipper, are all of the 4th magnitude. The star in the end of the handle is marked *Lambda*, and is placed in the bow of Sagittarius, just within the Milky Way.

This constellation is said to commemorate the famous Centaur, who changed himself into a horse to elude the jealous inquiries of his wife Rhea.

> "Midst golden stars he stands refulgent now,
> And thrusts the Scorpion with his bended bow."

This is the Grecian account of Sagittarius, but as this constellation appears

on the ancient zodiacs of Egypt, Dendera, Esne and India, it seems conclusive that the Greeks only borrowed the figure, while they invented the fable.*

TELESCOPIC OBJECTS OF INTEREST.

In *Elements of Descriptive Astronomy*, by H. A. Howe, the following objects of interest are given, as visible with small telescopes.

THE CONSTELLATIONS AT 9 P. M., AUGUST 1, 1897.

U Sagittarii, R. A. $18^h\ 8^m$, Decl. $-21°\ 5'$, a double star, the components being of the fourth and the ninth magnitudes, and at respective distances of 40″ and 45″. This star is in the northwest part of the constellation. The larger

* Geography of the Heavens, pp. 124-5. Burritt.

star is pale yellow, the smaller one blue. In the *Amateur Telescopist's Handbook* (p. 152) this star is termed a triple star, the third star being of the tenth magnitude, and of ruddy hue. In the explanatory text of Klein's *Star Atlas*, it is termed a quintuple star. The other two companions seen by Burnham, are merely faint points of light.

A star-cluster (4397) R. A. 18^h 11^m, Decl. — 18° 28′ is visible to the unaided eye, as an off shoot of the Milky Way. With a telescope, a cluster of stars closely grouped together, is to be seen. This cluster was discovered by Messier, 20th of June, 1764. It is nearly 1½° in diameter.

Another *star-cluster* (4261) R. A. 17^h 57^m, Decl. — 24° 23′, is a very beautiful object, discovered by Messier in 1764, and described by him as a cluster of stars. It really consists of several nebulæ, with a triple star and numerous others near it.

4403. *Nebula in Sagittarius*, R. A. 18^h 14^m, Decl. — 16° 15′. Klein describes this as follows: "It is something like a horse-shoe in shape. It was discovered by Messier, June 3d, 1764. He describes it as a luminous, starless streak, 5′ to 6′ in length, spindle-shaped not unlike the nebula in Andromeda, but very faint. There are two stars near it, parallel with the equator, but visible only in a telescope. In clear weather a very good view of this nebula may be obtained with an ordinary 3½-foot telescope. William Herschel was the first to get a perfect view of it. According to Holden, one arm of this nebula has changed its position. The spectroscope shows the nebula to be a mass of incandescent gas."

M. 25. *Star Cluster*, R. A. 18^h 25^m, Decl. — 19° 10′. A cluster of small stars, discovered by Messier, June 20th, 1764. It can be seen with quite a small telescope. Burnham has measured several double stars in it.

(All these objects can be found plainly marked in Map XI of Klein's "Star Atlas," the above facts being largely quoted from the explanatory text. Every owner of a small telescope, should add this book to his astronomical library, as he will find it of the greatest value, in studying the constellations. M. P.)

Trifid Nebula.

But the chief object of interest in this constellation is the Trifid Nebula, which is distinguished by the curious appearance of a bright mass, with dark avenues dividing it into three sections. Great changes seem to have taken place in this nebula, for a star which was seen in one of the dark lanes, early in the nineteenth century is now involved in the nebulous star-mist. "The star has not changed its position with respect to neighboring stars, therefore the nebula must have changed. Such is the result of an investigation, made by Professor Holden"*

Miss Clerke describes this nebula as follows: "The 'Trifid' Nebula in Sagittarius (M. 20) has a dark central space. The three great *lobes* of which it consists are divided by a sort of three-forked rift or vacant area, abruptly and uncouthly crooked, and quite void of nebulous light. These tracts of darkness are *thoroughfares*. They run right through, from the brilliant centre to the dim circumference of the nebula. A conspicuous multiple star, placed just at the sharp inner edge of one of the luminous detachments, probably exercises a predominant influence over them all; and corresponding ascendency may be claimed for a single star a little to the north, from which, as Herschel says, 'a fourth nebulous mass spreads like a fan or downy plume.' So far does it spread, that Sir John Herschel surmised a connection between it and another great nebula (M8) which, since it is composed of 'nebulous folds and masses, surrounding and including a number of oval dark vacancies,' might be termed the 'Lagoon' nebula. Its intermixture with a fine cluster has also been observed."

* Elements of Descriptive Astronomy, p. 259. By H. A. Howe.

"The spectrum of the Trifid nebula consists mainly of the inevitable ray at 5005, with a trace of the hydrogen *F*, and its light impresses the eye with a corresponding effect of greenish color. Photographic investigations of the subject can be pursued only in more southern latitudes than ours."*

* System of the Stars, pp. 283-4. By Agnes M. Clerke.

What is a Nebula?

Faintly outlined against the dark background of the sky, the telescope reveals misty, cloud-like objects, the material out of which stars are made, otherwise known as nebulæ or star-mist. They represent probably, the nucleus of future stars, solar systems that may be formed in vast epochs of time, when the lustre of Arcturus and Sirius shall have grown dim. In many of the nebulæ, stars are sprinkled over the cloud-like masses like dew over fern leaves, others are still in a chaotic state, whilst the material to form yet other nebulæ, may at present be represented by minute particles of matter now floating in the star-depths, later to reunite, and form in the ages to come, other worlds and other systems. They are:

". . . part of one stupendous whole
Whose body Nature is, and God the soul."

"The discovery that the nebulæ are probably masses of glowing gas is of capital importance, as tending to substantiate the view of Sir William Herschel, that these masses are the crude material out of which suns and systems are forming. This view was necessarily an almost purely speculative one on the part of that distinguished astronomer; but unless we suppose that the nebulæ are objects of almost miraculous power, there must be some truth in it. A nebulous body, in order to shine by its own light, as it does, must be hot, and must be losing heat through the very radiation by which we see it. As it cools, it must contract, and this contraction cannot cease until it either becomes a solid body or a system of such bodies revolving round each other.*

Constellation of Aquila, the Eagle.

According to the Grecian legend, this is the eagle that Jupiter kept beside his throne. It is supposed to have been Merops, a king of the island of Cos, in the Archipelago, and the mother of Phaeton, who was transformed into an eagle and placed among the constellations. Some of the ancient poets say that this is the eagle which furnished Jupiter with weapons in his war with the giants†:—

"The tow'ring Eagle next doth boldly soar,
As if the thunder in his claws he bore:
He's worthy Jove, since he, a bird, supplies
The heaven with sacred bolts, and arms the skies."

—*Manilius.*

This constellation is a rich and beautiful constellation, lying directly in the Milky Way. It contains 276 stars, including one of the first magnitude, nine of the third, and seven of the fourth. It is distinguished by its leading brilliant Altair, *alpha Aquilæ*.

Altair.

"Altair is a brilliant star of the first magnitude with a beautiful spectrum (Vogel; Class I a). It has a companion star of the tenth magnitude, of violet

* Popular Astronomy, p. 464. Professor Newcomb.
† Geography of the Heavens, p. 126. Burritt.

hue, Altair being pale yellow. There are several fainter stars near to the primary. Burnham saw over a dozen with his great refractor."* In the Harvard photometry, Altair is rated strictly of the first magnitude and it gives three times as much light as the pole-star. Of the ten stars measured at Yale, Altair was found to be at a distance of 16.4 light-years (parallax 0″.199). Altair is a million times as far from us as the Sun, its light taking sixteen years to reach us, although light travels at the phenomenal rate of about 186,330 miles a second (according to the latest determinations of Newcomb and Michelson). Altair is one of the stars from which the Moon's distance is taken for computing longitude at sea. Its mean declination is nearly $8\frac{1}{2}°$ N. and it culminates about six minutes before nine o'clock, on the last day of August. Ovid alludes to the rising of this constellation, or rather to that of Altair, as follows:—

"Now view the skies
And you'll behold Jove's hooked bill bird arise."

Altair can be easily traced in this constellation, as it is the only one of the first magnitude, and on each side of it are two stars of the third magnitude, namely Beta and Gamma, comrades, as it were, in the journey through the star-depths.

TELESCOPIC OBJECTS OF INTEREST.

Eta Aquilæ (R. A. 19^h 46^m, Decl. $+ 0° 42'$), $8°$ south of Altair, is a well-known variable star having a period of 7 days, 4 hours, $14^m.2$, the period at present slowly increasing. Its greatest brightness diminishes from the third to the fourth magnitudes, when it again waxes brighter and brighter, until it again appears as a star of the third magnitude. Its changeable appearance was recognized by Pigott, in 1784. Its variations can be well seen by comparing it for a few nights with Theta and Iota, which are near by. This star is a good test for a three-inch telescope on a fine night.

Beta Aquilæ (R. A. 19^h 49^m, Decl. $+ 6° 7'$) is a star of the fourth magnitude, and of a pale red tint. There are several faint stars near it.

CONSTELLATION OF DELPHINUS.

About $14°$ N. E. of the Eagle, is the beautiful little group of stars, known as the Dolphin, (*Delphinus*), containing 51 stars, including five of the third magnitude, but none larger. It is easily distinguished, on account of the four principal stars in the head, forming a diamond-shaped figure. To many this cluster is known by the name of *Job's Coffin*, though it is difficult to trace the origin of this name. The four stars in the Diamond are *Alpha*, *Beta*, *Gamma* and *Delta*.

According to mythology, "the Dolphin was transformed into a constellation by Neptune, because one of these beautiful fishes had persuaded the goddess Amphitrite, who had made a vow of perpetual celibacy, to become the wife of that deity."† According to another legend, "the ancients said the Dolphin represented the very animal on whose back, the famous musician Arion rode through the sea after his escape from the sailors who tried to murder him. It presents a very pretty sight to the opera glass."‡

GAMMA DELPHINI.

Gamma Delphini (R. A. 20^h 41^m, Decl. $+ 15° 42'$) is a star of the fourth magnitude, golden-yellow in color, and can be easily seen with a three-inch telescope. It has a companion star of the fifth magnitude, at a distance of 11″.

* Klein's Star Atlas, p. 62.
† Geography of the Heavens, p. 128. Burritt.
‡ Astronomy with an Opera-Glass, p. 55. Garrett P. Serviss.

LYRA, THE HARP.

In the olden maps this constellation has the appearance of a harp, and it was generally supposed that it was the celestial Lyre, with which Orpheus charmed the wild beasts of the forest. According to the legend, he played with such a masterly hand, that even the most rapid rivers ceased to flow, and the mountains came to listen to his song.*

The constellation Lyra is situated directly south of the first coil in Draco, between the Swan on the east, and Hercules on the west, and when on the meridian it is nearly overhead. It contains 166 stars, including one of the first magnitude, two of the second and two of the fourth.

"There Lyra, for the brightness of her stars,
More than their number eminent: thrice seven
She counts, and *one* of these illuminates
The heavens far around, blazing imperial
In the *first* order."

THE LEADING BRILLIANT, VEGA.

This star of "the first order, blazing with imperial luster, is Vega, and its surpassing brightness has attracted the admiration of astronomers in all ages. It is one of the brightest stars in the northern hemisphere, and has near it several faint stars, but their connection with it is merely optical. Its right ascension is $18^h\ 33^m$, declination $+\ 38°\ 40'$.

Vega is a splendid star of the first magnitude and when the telescope is directed towards it, it presents a brilliant appearance. It is of a sapphire hue, but in describing it, Captain Noble remarks: "it is impossible to reproduce in black and white the vivid blue blazes and the mouldings and twirlings of the diffraction rings which surround the great star. In an ordinary telescope Vega appears as a single star, but with a three-inch telescope a small blue companion star of the tenth magnitude is seen, distant 48".1. A nine-inch object glass shows two small companions, within a few seconds of Vega. "In the great Harvard refractor, Vega is seen with no less than 35 companions. I imagine that all these stars, and others which can be seen in neighboring fields, indicate the association of Vega with the neighboring stream of the Milky Way †

Seen with an opera-glass the delicate blush tinge in its light is noticeable. "There is no possibility of mistaking this star because of its surpassing brilliancy. Two faint stars close to Vega on the east make a beautiful little triangle with it, and thus form a further means of recognition, if any were needed. Your opera-glass will show that the floor of heaven is powdered with stars, fine as the dust of a diamond, all around the neighborhood of Vega, and the longer you gaze the more diminutive twinklers you will discover ‡

SPECTRUM OF VEGA.

"In November, 1890, Mr. A. Fowler exhibited to the Royal Astronomical Society, photographs of the spectrum of Vega with indicate that it is a spectroscopic double of the B Aurigæ and Rho Ursæ Majoris type. The principal lines are due to Hydrogen. The separation of the K line, within a few hours, indicated a circular orbit and a period of revolution of about 24.68 hours. This duplication of the K line, has not (1891) been confirmed by photographs taken by Pick-

* Geography of the Heavens, p. 129. Burritt.
† Half Hours with the Telescope. p. 48. By R. A. Proctor.
‡ Astronomy with an Opera-Glass. p. 49. Garrett P. Serviss.

ering, Vogel, and the Henry Brothers."* Miss Agnes Clerke refers to its spectrum as follows: "A photograph of the spectrum of Vega obtained with one hour's exposure contained twelve strong lines, forming a group in obvious rhythmical connection, and crowding together in an accelerated proportion as their wave-lengths shorten. A common origin for the entire series at once suggests itself, and, on the ground that its two most refrangible members were already known as hydrogen lines, Dr. Huggins did not hesitate to pronounce hydrogen responsible for all. His inference has since been amply justified. Seven of them proved to have been, a short time previously, photographed directly from glowing hydrogen, by Professor H. W. Vogel (*Astr. Nach.*, No. 2301) and the entire series was similarly procured later by M. Cornu (*Journal de Physique*, t. v. p. 341 (1886). But with extreme difficulty. Although the purified gas filling the capillary tube placed in front of the slit was excited by powerful electrical discharges its highest radiations took no less than three hours and a half to get satisfactorily printed. Some idea may thus be gained of the intense incandescence reigning in the remote stellar atmospheres from which they were first derived."†

TELESCOPIC OBJECTS OF INTEREST.

Epsilon Lyræ is a wonderful multiple system. If our observer has very good eyesight, he will distinctly recognize it as a double star, seen with the unaided eye, but more probably he will only notice that it appears lengthened in a north and south direction. With an opera-glass, it is easily seen double, and with a high power each of the components is seen to be double. In the "finder," the star is again easily divided. "Applying a low power, to a three-inch telescope, we see Epsilon as a wide double, the line joining the components lying nearly north and south. The southernmost component is called ε^1, the other ε^2. Seen as a double, both components appear white. Now if the observer's telescope is sufficiently powerful, each of the components may be seen to be itself double. First try ε^1, the northern pair. The distance between the components is 3″.2, their magnitudes 5 and $6\frac{1}{2}$, and their colors yellow and ruddy. If the observer succeeds in seeing ε^1 fairly divided, he will probably not fail in detecting the duplicity of ε^2, though this is rather a closer pair, the distance between the components being only 2″.6. The magnitudes are 5 and $5\frac{1}{2}$, both being white. Between ε^1 and ε^2 are three faint stars, possibly forming with the quadruple a single system.

"Let us next turn to the star *Zeta Lyræ*, R. A. 18^h 41^m, Decl. + 37° 29′. This is a splendid but easy double. The components are very nearly equal in magnitude, in color topaz and green, the topaz component being estimated as of the fifth magnitude, the green component intermediate between the fifth and sixth magnitudes. Klein gives the topaz component as of the fourth magnitude. The actual distance between the components of Zeta Lyræ is 44″, or about one-fourth of the distance separating Epsilon ^{1} from Epsilon ^{2}."‡ With a field-glass, Zeta is double.

The star Delta Lyræ is double, one component being orange, the other blue. R. A. 18^h 49^m 52^s, Decl. + 36° 50′ 3.

Beta Lyræ (Sheliak) is a variable with three companions, a pretty spectacle when seen with a telescope. The primary is grey-white, ranging from $3\frac{1}{2}$ to $4\frac{1}{2}$ magnitudes in a period of 12 days, 21 hours and 53 minutes, with a double maximum and double minimum. It has four companions, but only three can be seen with the telescope. It took our keen-eyed astronomer, Burnham, to find the

* Klein's "Star Atlas," p. 59.
† System of the Stars, p. 38. Agnes M. Clerke.
‡ Half Hours with a Telescope, pp. 49-50. R. A. Proctor.

fourth, which is a very faint star of the eleventh magnitude. The three companions are *B* of the eighth magnitude and pale grey; *D*, 8½, faint yellow; *E*, 9, of a lilac hue. "Beta Lyræ is an example of Class IV, of variable stars, this class including those stars of short periods, the light of which varies smoothly and regularly. Beta Lyræ is of the fourth magnitude, and varies half a magnitude on each side of this. The period is nearly thirteen days, during this time the star first reaches a maximum of the 3.4 magnitude, then sinks to the 3.9 magnitude, next rises to the 3.4 magnitude and finally sinks to the 4.5 magnitude. These changes are thought to be due in some way to the action of one or more companions revolving about the main star."*

This variability can be observed with an opera-glass, and you may watch the variations, which run through a regular period of about 12 days 21¾ hours for yourself.

The stars Gamma[1] and Gamma[2] can be seen with a three-inch telescope in a single field, the distance between them being about half the Moon's mean diameter. The former is quadruple, the components being yellow, blue, pale blue and of a bluish tint.

RING NEBULA.

Nearly midway between Beta and Gamma lies the wonderful ring-nebula 57 *M*, which was discovered in 1772, by Darquier, at Toulouse. It is seen as a ring of light with very moderate telescopic power. In a good 3½-inch telescope, the nebula exhibits a mottled appearance and a sparkling light. Larger instruments exhibit a faint light within the ring; and in Lord Rosse's great telescope "wisps of stars" are seen within, and faint streaks of light stream from the outer border of the ring. This nebula has been subjected to spectrum analysis by Mr. Huggins. It turns out to be a gaseous nebula! In fact, ring-nebula—of which only seven have been detected—seem to belong to the same class as the planetary nebulæ, all of which exhibit the line-spectrum indicative of gaseity. The brightest of the three lines seen in the spectrum of the ring-nebula in Lyra presents a rather peculiar appearance, "since it consists," says Mr Huggins, "of two bright dots, corresponding to sections of the ring, and between these there is not darkness, but an excessively faint line joining them. This observation makes it probable that the faint nebulous matter occupying the central portion is similar in constitution to that of the ring."†

"A minute star of the 10th magnitude follows the nebula closely. The 36-inch refractor of the Lick Observatory shows three stars in the central space, where Lord Rosse's drawing gives a blank field." (See *Nature*, August 9th, 1888). "The photographs taken at the Algiers Observatory in 1890 show that the nebulosity spreads towards the centre, and that the central star there is surrounded by three very feeble stars. Miss Clerke, summing up the evidence as to its form (*Nature*, March 5th, 1891) pronounces the nebula elliptical."‡

PLANET NOTES FOR AUGUST.

H. C. WILSON.

Mercury, *Mars*, and *Jupiter* are evening planets together, all low down in the western sky at sunset. Mercury will be at greatest elongation, east of the Sun 27° 18′ on August 26 at 4^h P. M., Central Standard Time. About that time, for a

* Descriptive Astronomy, p. 248. Herbert A. Howe.
† Half Hours with the Telescope, pp. 51-2. R. A. Porctor.
‡ Explanatory text. Klein's *Star Atlas*. p. 60.

week or ten days, it will be possible to see the planet with the naked eye, by looking due west an hour after sunset. Mars will be very near to Mercury during the last half of the month, but Mercury will have to turn back toward the Sun before the two planets come to conjunction. Mercury will probably be the brighter of the two and be picked up first in the twilight. Jupiter is in the same part of the sky, but will then be below Mercury. The two planets will be in conjunction, Mercury 1° 14′ south of Jupiter at midnight August 12. It may be possible, even on that evening, soon after sunset, to catch a glimpse of Mercury.

Venus is still the bright "morning star" rising between three and four hours before the Sun. The declination of Venus is now about 21° north, so that her altitude, when she comes to the meridian at about 9^h A. M., is very high. This should be a very favorable time for studying the surface markings of the planet by daylight observations during the forenoon. The phase is becoming more and more gibbous, 0.613 of the disk being illuminated on Aug. 1 and 0.730 on Aug. 21. Venus and the Moon will be in conjunction a little after noon, Aug. 24, Central time.

Saturn and *Uranus* are together, toward the southwest, between Scorpio and Libra. Both will be at quadrature, 90° east from the Sun, in August, Saturn on the 16th and Uranus on the 17th. They will be in conjunction, Uranus 1° 48′ south of Saturn, Aug. 25 at 6 P. M. Both will then be moving eastward, Saturn much faster than Uranus. We have had a few good views of Uranus lately with the 16-inch telescope but have been unable to see any markings upon the face of the planet. On one night a pair of light colored belts, extending in approximately the direction of the axis of the apparent satellite's orbits, was suspected, but no weight can be attached to the observation.

Neptune is morning planet with Venus, and is coming into better position for observation.

The Moon.

		Phases.	Rises. (Local Time.)		Sets. (Local Time.)	
			h	m	h	m
August	5	First Quarter	1	12 P. M.	10	22 P. M.
	12	Full Moon	7	10 "	6	10 A. M.
	20	Last Quarter	10	24 "	2	54 P. M.
	27	New Moon	4	40 A. M.	6	24 "

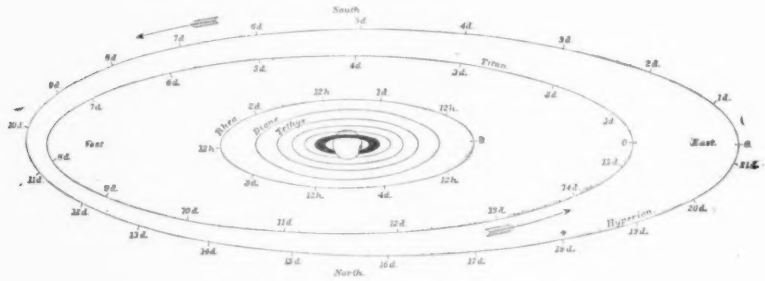
Occultations Visible at Washington.

Date 1897.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle from N pt. °	EMERSION. Washington M. T. h	m	Angle from N pt. °	Duration. h	m
Aug.	6	4 Scorpii	6.3	5	11	140	6	17	257	1	6
	6	π Scorpii	3.4	7	0	54	7	54	330	0	54
	6	B. A. C. 5347*	6 0	11	45	56	12	34	305	0	49
	8	B. A. C. 6194	5.1	12	21	89	13	23	239	1	2
	9	ψ Sagittarii	5.4	9	26	119	10	21	205	0	55
	9	χ Sagittarii*	5.6	14	57	40	15	47	277	0	50
	14	λ Piscium	4.5	12	23	42	13	43	238	1	21
	19	*g* Pleiadum	6.3	15	10	113	16	10	202	1	0
	19	19 Tauri	5.0	15	24	78	16	50	238	1	26
	19	21 Tauri	7.0	15	55	74	17	25	246	1	30
	19	20 Tauri	5.0	15	55	119	16	53	199	0	58
	19	22 Tauri	7.0	15	58	83	17	27	236	1	28

* Whole occultation below the horizon of Washington.

Saturn's Satellites.

[E = at east elongation; I = at inferior conjunction (south of planet); W = at west elongation; S = at superior conjunction (north of planet].



I. MIMAS.

Period $0^d\ 22^h.6$

Aug.	1	10 6	P. M.	E
	2	9 2	"	E
	3	7.8	"	E
	9	10.9	"	W
	10	9.5	"	W
	11	8.1	"	W
	17	11.1	"	E
	18	9.7	"	E
	19	8.4	"	E
	25	11 4	"	W
	26	10.0	"	W
	27	8.6	"	W

II. ENCELADUS.

Period $1^d\ 8^h.9$

Aug.	2	6.3	P. M.	E
	4	3.2	A. M.	E
	5	12.1	P. M.	E
	6	9 0	"	E
	8	5 9	A. M.	E
	9	2.7	P. M.	E
	10	11.6	"	E
	12	8.5	A. M.	E
	13	5.4	P. M.	E
	15	2 3	A. M.	E
	16	11.2	"	E
	17	8.1	P. M.	E
	19	5.0	A. M.	E
	20	1.9	P. M.	E
	21	10.8	"	E
	23	7.7	A. M.	E
	24	4.6	P. M.	E
	26	1.5	A. M.	E
	27	10.4	"	E
	28	7.3	P. M.	E
	30	4.2	A. M.	E
	31	1.1	P. M.	E

III. TETHYS.

Period $1^d\ 21^h.3$

Aug.	1	11.9	A. M.	E
	3	9 2	"	E
	5	6.5	"	E
	7	3.8	"	E
	9	1.1	"	E
	10	10.4	P. M.	E
	12	7.8	"	E
	14	5.1	"	E
	16	2.4	"	E
	18	11.7	A. M.	E
	20	9.0	"	E
	22	6 3	"	E
	24	3.6	"	E
	26	12.9	"	E
	27	10 2	P. M.	E
	29	7.5	"	E
	31	4.8	"	E

IV. DIONE.

Period $2^d\ 17^h.7$

Aug.	3	12.1	A. M.	E
	5	5 8	P. M.	E
	8	11.5	A. M.	E
	11	5.2	"	E
	13	10.9	P. M.	E
	16	4.6	"	E
	19	10.3	A. M.	E
	22	4.0	"	E
	24	9.7	P. M.	E
	27	3.4	"	E
	30	9.1	A. M.	E

V. RHEA.

Period $4^d\ 12^h.5$

Aug.	5	3.7	A. M.	E
	9	4 2	P. M.	E
	14	4.7	A. M.	E
	18	5.2	P. M.	E
	23	5.7	A. M.	E
	27	6.2	P. M.	E

VI. TITAN.

Period $15^d\ 23^h.3$

Aug.	4	2.3	P. M.	S
	8	11.5	A. M.	E
	12	8 8	"	I
	16	1.0	P. M.	W
	20	1.2	"	S
	24	10.4	A. M.	E
	28	7.8	"	I

VII. HYPERION.

Period $21^d\ 7^h.6$

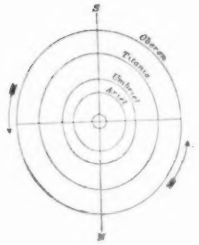
Aug.	4	10.7	A. M.	I
	9	5.7	"	W
	13	12.0	Midn.	S
	19	11.8	P. M.	E
	25	3.8	"	I
	30	11.1	A. M.	W

VIII. JAPETUS.

Period $79^d\ 22^h.1$

July	19	4.2	A. M.	E
Aug.	6	7.8	"	I
	27	4.7	"	W

The Satellites of Uranus.



ARIEL.

Period $2^d\ 12^h.489$

North.		South.	
Aug. 2	12.8 A. M.	Aug. 1	6.6 A. M.
5	1.3 A. M.	3	7.1 P. M.
7	1.8 P. M.	6	7.6 A. M.
10	2.3 A. M.	8	8.1 P. M.
12	2.8 P. M.	11	8.6 A. M.
15	3.3 A. M.	13	9.1 P. M.
17	3.8 P. M.	16	9.6 A. M.
20	4.3 A. M.	18	10.0 P. M.
22	4.8 P. M.	21	10.5 A. M.
25	5.3 A. M.	23	11.0 P. M.
27	5.8 P. M.	26	11.5 A. M.
30	6.3 A. M.	28	12.0 Midn

TITANIA.

Period $8^d\ 16^h\ 942$

North.		South.	
Aug. 3	12 2 A. M.	Aug. 7	8.6 A. M.
11	5.1 P. M.	16	1.5 "
20	10.0 A. M.	24	6 5 P. M.
29	2.9 A. M.	Sept. 2	11.4 A. M.

OBERON.

Period $13^d\ 11^h.119$

North.		South.	
Aug. 10	3.1 P. M.	Aug. 3	9 6 P. M.
24	2.2 A. M.	17	8.7 A. M.
		30	7.8 P. M.

UMBRIEL.

Period $4^d\ 3^h.460$

North.		South.	
Aug. 1	12.3 A. M.	Aug. 3	2.0 A. M.
5	3 8 "	7	5.5 "
9	7.2 "	11	8.9 "
13	10.7 "	15	12.4 P. M.
17	2.1 P. M.	19	3.9 "
21	5.6 "	23	7.3 "
25	9.0 "	27	10.8 "
30	12.5 A. M.	32	2.2 A. M.

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.

1897.

	d	h
Sept.	1	20
	4	8
	6	20
	9	8
	11	20
	14	8
	16	19
	19	7
	21	19
	24	7
	26	19
	29	7

ALGOL.

Sept.	1	21
	4	17
	7	14
	10	11
	21	22
	24	19
	27	16
	30	13

λ TAURI.

1897.

	d	h
Sept.	17	22
	21	21
	25	20
	29	19

R CANIS MAJ.

Sept.	1	21
	7	13
	8	17
	9	20
	16	16
	17	19
	18	22
	24	14
	25	18
	26	21

S CANCRI.

Sept.	6	17
	25	17

S VELORUM.

1897.

	d	h
Sept.	4	16

U CORONÆ.

Sept.	4	13

U OPHIUCHI.

Sept.	4	4
	12	14
	20	23
	29	8

RS SAGITTARII.

Sept.	2	8
	4	18
	9	14

RS SAGITT. Con.

1897.

	d	h
	14	10
	21	16

Z HERCULIS.

Sept.	4	10
	8	9
	12	9
	16	9
	20	9
	24	9
	28	9

W DELPHINI.

Sept.	11	19
	16	14
	21	10

Maxima and Minima of Long Period Variables.

1897 October.

MAXIMA.		Day
103	T Andromedæ	29
678	U Persei	17:
715	S Arietis	19
782	R Arietis	31
845	R Ceti	19
1018	R Horologii	15:
1113	U Arietis	22
1635	R Reticuli	29
1803	T Leporis	25:
2676	U Monocerotis	20
3493	R Leonis	8
4521	R Virginis	14
5037	RR Virginis	12
5095	R Centauri	5

MAXIMA, Cont.		Day
5583	X Libræ	20
5770	R Herculis	23
5889	U Herculis	22
5928	T Ophiuchi	27:
5931	S Ophiuchi	26
6794	R Lyræ	27
6871	V Lyræ	10:
7404	R Microscopii	7
7571	V Capricorni	11
7659	T Capricorni	24

MINIMA.		
294	W Cassiopeæ	8:
466	U Piscium	5

MINIMA, Con't.		Day
976	T Arietis	1
1944	S Orionis	28
2258	V Aurigæ	4:
2676	U Monocerotis	2
3637	S Carinæ	6
4511	T Ursæ Maj.	23
4896	T Centauri	26
5338	U Bootis	31
5955	R Draconis	19
6512	T Herculis	8
6794	R Lyræ	4
6905	R Sagittarii	25
7106	S Vulpeculæ	30

The above ephemeris was computed for Popular Astronomy directly from the elements given in Chandler's Third Catalogue, with the following two exceptions:

U Cephei. Times from Chandler's revised elements, A. J. No. 396.

U Ophiuchi. Every tenth minimum. Period $20^h\ 8^m$.

Mira.

In *Astronomische Nachrichten* No. 3426 Dr. A. A. Nyland of the Observatory of Utrecht, gives a valuable report of his observations, extending from 1896 Aug. 5 to 1897 Mar. 10. When fainter than the 7th magnitude the star was observed with an aperture of 3 inches, the brighter phases with an opera-glass of 2 inches aperture and magnifying power of 3.3. The results of 38 observations give:

Minimum 1896 Sept. 2, 8.8 mag.
Maximum 1897 Jan. 11, 3.5 " } (scale of the D. M.)

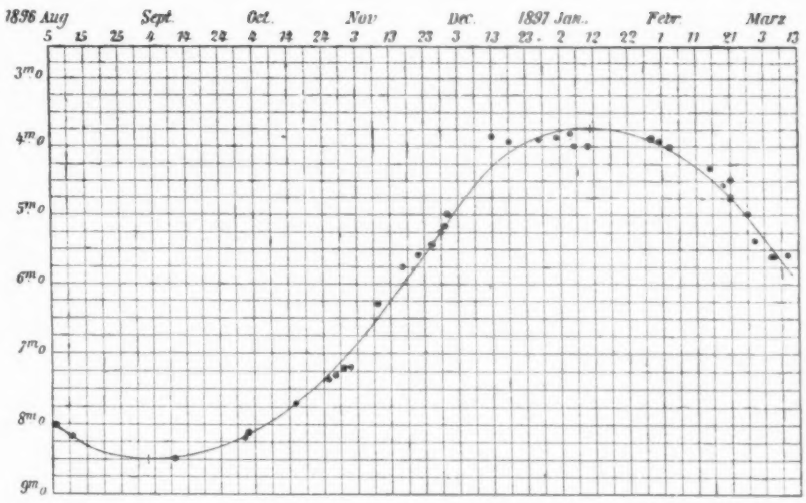
Dr. Nyland's graphic representation of the light curve is reproduced here and should be compared with that of Mr. H. M. Parkhurst, given in Popular Astronomy Vol. III, page 165.

Missing Durchmusterung Stars.

In *Astronomische Nachrichten* No. 3412, Dr. E. Weiss, director of the Vienna Observatory, reports that the D. M. star $+4°,3555$ was missed from the heavens 1892 May 21. Unfortunately, the aperture used in the observation is not given, so we cannot be certain just how faint the star was, but probably at least 12 inches was used, corresponding to a *minimum visible* of 13 or 14 and perhaps fainter. In No. 3424 of the *Nachrichten*, Professor Küstner gives the original Durchmusterung zone observations, 1854 May 30, and July 24, 9.5 mag. each date. The positions of the star in these two zones differ by 2′.1 in Decl. and $1^s.5$ in R. A., about three times the probable error of a D. M. position. The question thus arises whether two different stars were not observed. The accompanying chart on the scale of the D. M. will serve to identify the field, and the larger scale chart will show the fainter comparison stars. One evening's estimates 1897 July 1, give the following magnitudes:

a, 8.7; *b*, 8.3; *c*, 11.0; *d*, 11.4; *e*, 11.2; *f*, 11.4; *g*, 10.5; *h*, 11.5; *k*, 11.6; *l*, 11.3; *m*, 12.8.

Nothing was seen at *x* and *y*, these are the positions from the D. M. zone ob-



LIGHT CURVE OF MIRA, BY DR. A. A. NYLAND.

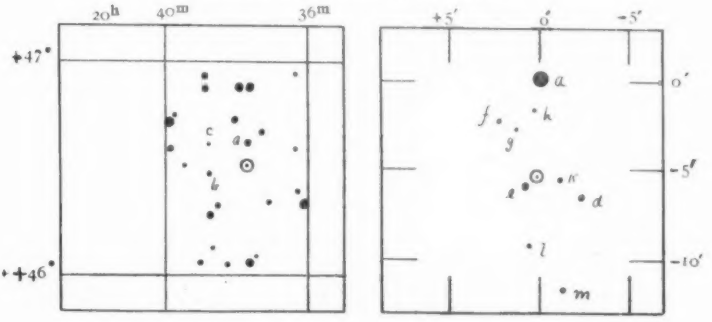
servations. It seems very probable that *d* is the star which was below the 13th mag. in 1892, and now is 11.4.

THE MISSING DURCHMUSTERUNG STAR, + 46°.3019.

The D. M. magnitude of this star is 9.2. It was missed from the heavens by Espin (Chandler's Third Catalogue, date of "missing" not given). The position of the missing star is indicated on the charts, but nothing was seen in the exact place. The comparison stars were estimated 1896 Sept. 30:

a, 9.1; *e*, 11.5; *f*, 10.8; *g*, 11.5; *d*, 10.3; *l*, 12.5; *k*, 12.1; *m*, 12.

MISSING D. M. STAR + 46° 3019.



4/5 Scale of the D. M. Larger Scale.

The distance of the star *e* from the place of the missing star is no greater than

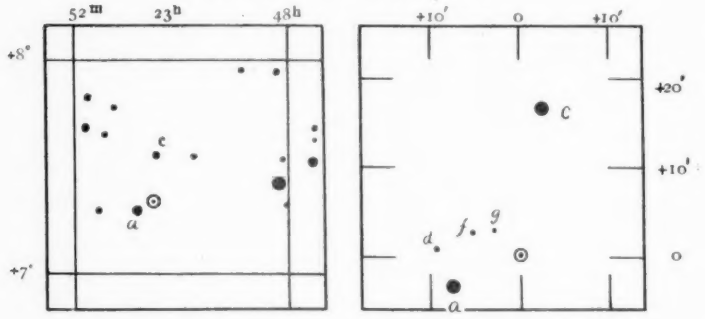
the uncertainty of the D. M. positions. However, no variation has been found in it between 1896 Sept. 30 and 1897 May 17.

THE MISSING DURCHMUSTERUNG STAR, + 7°.5106.

This is also in Chandler's list of missing stars in the Third Catalogue. It was observed by Argelander (Bonn VI) as 9.5 magnitude, 1854 Oct. 18, in the place

R. A. $23^h\ 50^m\ 28^s.48$, Decl. + 7° 20′ 8″.3, 1855.

MISSING D. M. STAR + 7°,5106.



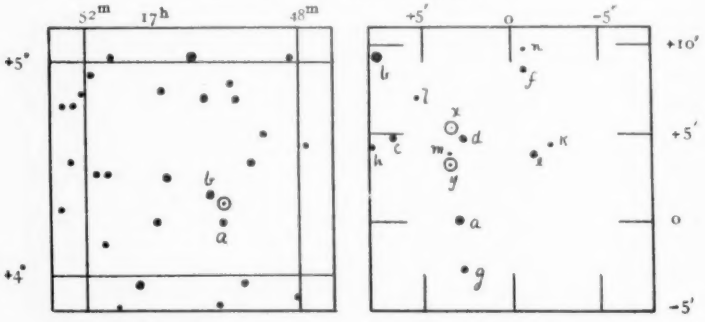
4/5 Scale of the D. M. Larger Scale.

On Oct. 26, 1896, I found an 11th magnitude star in the place

R. A. $23^h\ 50^m\ 27^s.7$, Decl. + 7° 20′.0, 1855.

In *Astronomische Nachrichten* No. 3405 Dr. Kreutz has the following note: "The star *BD.* 7,5106 to be sure is placed by Chandler among the 'Missing Durchmusterung stars,' but, so far as I know, has never been invisible, but only found 12 or 13 magnitude or fainter, by Tempel, 1885 Feb. 12 and 13. Compare *A. N.* Vol. 111, page 248, in which place the original observations of the *BD.* are given."

MISSING D. M. STAR + 4°,3555.



4/5 Scale of the D. M. Larger Scale.

Note on the three stars.—Although the evidence in favor of the variability of

none of the three can be said to be conclusive, they certainly deserve close watching. Their places are as follows:

°	h	m	s	°	′	
+ 4.3555	17	49	18	+ 4	21.5	1855
		51	32		22.1	1900
+ 46,3019	20	37	50	+ 46	30.1	1855
		39	19		39.7	1900
+ 7.5106	23	50	28	+ 7	20.1	1855
		52	46		35.2	1900

GENERAL NOTES.

Astronomical Work in American Observatories.—In order to let our readers know what is going on in the line of astronomical research in our own country, we recently addressed a card of inquiry to the Directors of the principal Observatories, asking each to give a brief statement of the work now being done. The substance of the replies is given in the notes which follow:

Washburn Observatory, University of Wisconsin—Replying to your note of June 26: Mr Flint is working up his stellar parallaxes determined with the meridian circle and will probably be occupied by it for some time to come. The observations are completed but the reduction is very laborious, least square solutions.

Personally I am keeping up my double star observations and am experimenting along a number of new lines, of which the most interesting is perhaps an investigation of the density of the supposed lunar atmosphere. Of course no one imagines the Moon to have an atmosphere comparable in density with that of the Earth, but the selenographers are insistent upon having one of say 1/500 of our own. It is this possible numerical limit that I am working on.

GEO. C. COMSTOCK.

Allegheny Observatory.—The work which I have had on hand for some time, and on which I am still engaged, is the photography of stellar spectra with orthochromatic plates. The results are excellent, but progress is slow on account of our smoky atmosphere. Last winter I made some photographic comparisons (already described in the *Astrophysical Journal*) of the spectra of Mars and the Moon. I have also been photographing the spectra of planets for the purpose of testing the accuracy of the spectroscopic method of determining rotation periods, and have spent some time trying to extend this method to planets whose rotation periods are yet unknown. JAMES E. KEELER.

Georgetown University Observatory—The staff of this Observatory consists of: Rev. John G. Hagen, S. J., Director; Rev. John T. Hedrick, S. J., Mr. Michael Esch, S. J., Assistant Astronomers. Father Hagen sends the following extracts from his annual report:

"The use made of the instruments has been substantially in the same lines as during the preceding years.

"The *small equatorial* has been used by Mr. M. Esch, S. J., for the observation of variable stars. The results which Mr. Hisgen, S. J., had obtained with the same instrument the year before have since been published in the ***Astron. Nachr.***

"The *photographic zenith telescope*, in charge of Father J. T. Hedrick, S. J., has been in constant use on every night sufficiently good for almost two years. This uninterrupted series cannot fail to give good and interesting results. It represents the *first* series of photographic determinations of the variation of latitude ever made, and is now the *only* photographic series extending over a complete period of these variations. The quantity to be measured is less than half a second of arc, smaller than any other quantity in practical astronomy. The results of our new method are indeed looked for by astronomers with great interest. Unfortunately, however, the measuring of the plates had to be postponed for the lack of a suitable micrometer. As the Observatory is not yet provided with an endowment, we are again dependent on the interest and liberality of our friends.

"The photographic work done with the *Ertel Transit* was published by the munificence of Mr. P. F. Collier, of New York, and has been distributed to all Observatories. A continuation of these photographic transits of stars with the new nine-inch transit instrument had to be postponed, owing to the illness and retirement of one of our assistants mentioned above.

"The *twelve-inch equatorial* has been devoted for the last five years to the construction of an Atlas of the Variable Stars. The first public mention of the plan and of the progress of the work was made last summer at the Astronomical Congress in Bamberg, and attracted considerable attention on the part of all present. A specimen copy of the charts was shown to the learned assembly and criticism was invited. With one voice the meeting commended the work and acknowledged the need of such an atlas. The entire publication will comprise more than two hundred charts. The printing will soon begin. The address of Father Hagen on this subject was published by the astronomical society in its *Vierteljahrsschrift* (Vol. 31, part 4). An English abstract may be seen in POPULAR ASTRONOMY for May, 1897.

"Another plan of work deserves mention—the publication of the collected works of Leonard Euler. Preparations for this plan were made by the publication of an "Index Operum" of this great scientist by the Director of the Observatory. At the meeting of scientists and physicians at Frankfort last summer Father Hagen, S. J., presented this index in the form of an octavo volume, and explained the manner in which the eight hundred titles of Euler's treatises had been verified and put in good order, and finally added that this index was intended as a preliminary to the edition of Euler's work. When he declared his hope that some American patron of science would give the means for this publication he aroused universal applause in the learned assembly. Several mathematicians arose and welcomed the plan as most desirable and useful. Father Hagen's address was printed in the proceedings of the society.

"We take this opportunity to inform our friends that the complete edition of Euler's works would comprise about twenty-five large quarto volumes, and that a publisher has already engaged himself to undertake this work on condition that $20,000 be placed at his disposal. A few remarks will show that a great opportunity is here offered to American patrons of science.

"We have in this country numerous examples of observatories, laboratories, lecture halls, libraries, etc., generously donated to scientific institutions. Experience has proved that, unless a further and much larger donation is made as a foundation for the support of able scientific men who shall maintain and employ the equipment, the gift frequently turns out a disgrace both to the institution and the benefactor. It would be an easy matter, for instance, to enumerate not a few telescopes which bear the names of their patrons only to remind us that the donors have buried principal without interest. Even if a scholarship or a chair

is founded, the patron has no absolute guarantee of its being held with honor for all time to come.

"The case is entirely different with the edition of Euler's collected works. Once published it will need no further attention; it is complete in itself, an everlasting monument to Euler, to its munificent patron and to this country."

U. S. Naval Observatory.—In compliance with the request made in your postal card, postmarked June 30, I have much pleasure in supplying the following statement as to the work done at this Observatory during the last 12 months:

With the 26-inch equatorial telescope observations have been made on the following named objects: Brook's Periodic Comet 1896 VI; Giacobini's Comet 1896 V; Perrine's Comet 1897 I; Perrine's Periodic Comet 1896 VII; the Satellites of Mars, and many double stars. The diameters of Mercury and Venus have been measured whenever sufficiently favorable conditions occurred, and some experimental work has been done with the spectroscope.

With the 12-inch equatorial telescope the following named objects have been observed: Flora (8), Psyche (16), Nemausa (51), Sappho (80), Sylvia (87), Amalthea (113), Electra (130), Ismene (190), Nephthys (237), (346), (386), (387), Perrine's Comet 1897 I, Perrine's Periodic Comet 1896 VII, the positions of certain small stars, the diameter of Venus, 8 occultations of stars by the Moon, and 5 eclipses of Jupiter's satellites. On Tuesday and Thursday evenings of each week, weather permitting, the 12-inch telescope has been used for the exhibition of celestial objects to visitors. During the year 3,260 permits were issued to such visitors by the Observatory, and a large additional number were issued by the Bureau of Equipment.

With the 9-inch transit circle the following named observations were made: Stars required for completing the zone $-13°\ 50'$ to $-18°\ 10'$, 435; zero stars for zones, 148; American Ephemeris stars, 2,832; miscellaneous stars, 109; wire interval stars, 73; Sun, 177; Moon, 122; Mercury, 87; Venus, 140; Mars, 44; Jupiter, 45; Saturn, 59; Uranus, 58; Neptune, 39; Flora, 6; Psyche, 6; Nemausa, 13; Sappho, 4; (346), 7; total, 4,404. As the reductions are very much behind, it was thought best to limit the work of this instrument to observations of the Sun, Moon and planets, together with such stars as were wanted for special purposes, and the minimum number of ephemeris stars necessary for determining instrumental constants.

The prime vertical transit instrument has been used in connection with the meridian instrument, Stackpole and Brother No. 1,502, for determining variations of latitude and the constants of aberration and nutation, precisely as in former years, except that the stars 40 Aurigæ and 1,450 Groombridge have been added in order to increase the possible number of observations at certain seasons of the year. The observations actually obtained were as follows: With the prime vertical transit instrument, μ Andromedæ, 17; α Canum Venaticorum, 35; η Aurigæ, 37; γ Boötis, 30, 40 Aurigæ, 4; Groombridge 1450, 6; α Lyræ, 111. With the zenith telescope, α Lyræ, 120. Total, 360 observations.

We have all been intensely interested in the spicy article on page 166 of the July number of "Popular Astronomy," wherein you so graphically comment on a report that peace and quiet at the Naval Observatory has been a little disturbed during recent months; but alas, alas, the more we have read the article the more mysterious it all become. There is not a man here who has ever heard of any such disturbance of the peace, and we are all hoping that you will lay us

under yet greater obligations by stating clearly in the next number of your able journal who is quarrelling, and what they are quarrelling about.

WM. HARKNESS,
Professor of Mathematics, U. S. N.,
Astronomical Director.

Washington, D C., July 13, 1897.

The University of Minnesota, Minneapolis.—During the collegiate year, the greater part of the time and instruments is devoted to teaching. Only during the summer months can original work be carried on to any extent. Our work is along two lines. 1st, measurement of double stars, from a list supplied by Burnham from stars especially needing measurment. We have just sent our year's work to the *Astronomical Journal.*

2d. Photographing interesting nebulæ and their neighborhood, with the intention of measuring their position with reference to surrounding stars, and perhaps with a view of obtaining annual parallax if it seems practicable. We have obtained several fine photographs already. We do not expect to work this up rapidly as we have not the time nor force for the purpose.

F. P. LEAVENWORTH.

Chamberlain Observatory, University of Denver.—Professor H. A. Howe writes from Hyamis Port, Mass., under date July 2, 1897:

"I have come to the seashore for Mrs. Howe's health and so the Observatory is closed for the summer. Mr. Saegmuller is building a special micrometer for me, for rapid determinations of $\Delta\alpha$ and $\Delta\delta$, and when I return in September I hope to go to work on nebulæ and stray comets."

The Lick Observatory.—The last legislature of California appreciated its great University. It unanimously voted a large increase in the University's income from state taxation. We learn from recent San Francisco papers that the regents of the University were thereby enabled to increase salaries, provide for new departments, and strengthen the old ones. The Lick Observatory's share of the increase was about $2,600 per annum, for salaries.

New Superintendent of the Naval Observatory.—Commander Charles H. Davis has been detailed to duty as superintendent of the Naval Observatory on the retirement of Commodore R. L. Phythian on the 21st instant. Commander Davis was special aid to the Princess Eulalie, of Spain, on the occasion of her visit to this country during the World's Columbian Exposition. At present he is a member of the naval inspection board, temporarily engaged in making a special investigation of the New York navy yard.—The Evening Star, Washington, D. C., July 8, 1897.

It is said that Commander Davis is the son of a former superintendent of the Naval Observatory and is therefore competent to perform the duties of the office.

The Rotation of Venus--Gravitation.—In your July number Mr. Monck asks some questions which we shall endeavor to answer without repeating, simply referring to his numbers.

1. If a body such as Venus now is were started in her orbit without rotation relative to the Sun, she would continue so forever. But as we suppose Venus to have been separated from the Sun like the other planets, it is certain that at birth her condition was very different from what it is now. The exact process by which

the planet separated has not yet been made out with certainty, but recent investigations indicate that they were detached as lumpy masses (not rings) and that on first separating the mass, say of Venus, occupied from say 10 to 50 times its present dimensions, and showed one face to the central nebula. But as the mass had initially a certain moment of momentum about its axis of rotation,(which would on this supposition be about perpendicular to the plane of the orbit) it would on contracting rotate more rapidly; and hence I think at some stage of its history it would certainly have turned on its axis more rapidly than it revolved in its orbit. The same is true of the formation of our Moon, Jupiter's satellites, the double stars and other heavenly bodies. Tidal friction is certainly the cause by which the rotations of our Moon, Mercury and Venus have been destroyed. Under the conditions supposed it would continually reduce the rotation whatever be the position of the axis. It is as certain as anything can be that none of our planets or satellites were captured, but that all formed from the masses about which they revolve.

2. Tidal friction would finally render the period of rotation and revolution exactly coincident.

It is not necessary for those who do not observe Venus and Mercury under the best conditions to form any opinion as to the fact of the isochronism in the periods of the rotation and of revolution; this may be left to those who alone are capable of deciding facts, not by opinion (as the Aristotelians did in Galileo's time), but by elaborate and careful observations made by skilled observers. Just too many persons in our time are deciding all manner of things with Papal infallibility,whether they are acquainted with the facts or not. Their behavior is something like that of an infatuated philosopher of the middle ages, who when told that the fact did not agree with his theory, replied, "So much the worse for the facts."

3. Several astronomers within the last 20 years have tried to find whether gravitation is propagated with a finite velocity, chiefly by certain criteria deduced from the motions of Mercury and Venus, but no very decisive result has been obtained. Laplace has given more attention to this question than any one else, and he found from the secular acceleration of the Moon's motion that if the velocity be finite at all it must surpass that of light at least 50 million times. It is certain that any velocity which gravitation may have has no relation to that of light and electricity. There is nothing now known to indicate that time is required in the transmission. The problem however, is perhaps the most difficult with which science has ever grappled, and a good test can hardly be devised in the present state of Astronomy. Until certain small anomalies in the planetary and *lunar* theory are better accounted for it would hardly be permissible to follow the method adopted by Laplace.

S.

Professor G. D. Swezey, Director of the Astronomical Observatory of the University of Nebraska, Lincoln, Neb., is spending his vacation in astronomical study under Professor Comstock at the Washburn Observatory.

Eclipse Expedition to India.—Regent C. F. Crocker, of the University of California, has added another to his already numerous gifts to astronomical science, by offering to defray the expenses of an expedition from Lick Observatory to witness the total solar eclipse, which is to take place in India on Jan. 21, 1898. At a meeting of the Board of Regents on June 23, Professor Campbell was "authorized to proceed, without loss of salary, to India on or about October 20, 1897, to establish an eclipse station, returning to Mount Hamilton on or before

June 1, 1898." The Director of Lick Observatory was instructed to prepare general plans and directions for the expedition and authorized to furnish such instruments and supplies as can be spared and as are necessary for the expedition.

Annals of Harvard College Observatory.—Vol. XXVI, Part II, contains Miscellaneous Investigations of the Henry Draper Memorial, by Edward C. Pickering, Director, aided by Mrs. M. Fleming, Assistant. It is mainly a discussion of some of the photographic results obtained at Arequipa, Peru, under the heads: Distribution of Stars in Clusters; Measurement of Positions; Measurements of Brightness; Spectra of Stars in Clusters. These are all very interesting, as well as of great scientific value, and are accompanied by a number of fine photo-engravings, among which we note especially, The Milky Way in Sagittarius, the two Magellanic Clouds, the Vicinity of η Carinæ, the star clusters ω Centauri and 47 Tucanæ and the Spectra of Stars in Carina.

Annual Report of the Paris Observatory.—The report by the Director, M. Loewy, refers in the opening paragraphs to the great loss of the Observatory by the death of the former director, M. Tisserand, and pays high tribute to the memory of that illustrious astronomer and mathematician. A short account is given of the Astro-Photographic Congress which met at Paris in 1896, and of the difficult problems which have to be solved in the great work of charting the heavens. Up to May 1896, only 11,557, out of the 22,054 plates necessary to cover the whole sky, had been obtained for the construction of the Catalogue, and probably only 3,500 with sufficient exposure for the Chart. Of the eighteen Observatories engaged in this work those of Alger, The Cape, Greenwich, Helsingfors, Melbourne, Oxford, San Fernando, and Paris have nearly finished the series of plates for the Catalogue; work is being prosecuted vigorously at Bordeaux, Catane, Potsdam, Tacubaya, Toulouse, The Vatican (Rome), and at Sydney, but, for various reasons, the observatories of La Plata, Rio de Janeiro and Santiago have not begun their task. It is expected that the work of taking the necessary photographs will be finished by 1900. The measurement of the photographs and publication of the results will take much longer. In the Paris zone, between the limits $+18°$ and $+24°$, there are found upon the chart plates about 2,000,000 stars.

The work of M. Bigourdan, in determining precise positions of the nebulæ between the north pole and 30° south declination, has been prosecuted with vigor. It will require three years more to complete the task.

Many of the difficulties encountered in attempting to construct a photographic atlas of the Moon have been vanquished and a portion of the Atlas has been issued. Another portion will be issued this year.

M. Deslandres has continued his spectroscopic work, except while absent on the Japan eclipse expedition. A large amount of work, which cannot be mentioned here, has been done by the various departments of the Observatory.

Jupiter Observations at the Manora Observatory 1895-1896.—Mr. Leo Brenner has kindly sent us the results of his observations of Jupiter during the opposition of 1895-6. The volume contains the discussion of the positions and movements of a large number of spots upon the planets surface, accompanied by 8 colored lithographic plates of maps and drawings of the surface markings.

For Sale.—A new 6 in. equatorial mounting, with circles, etc. (Class B. of W. and D. Mogey, Bayonne City, N. J.) Address M. A. Bigelow, No. 11 Pleasant St., Stamford, Conn.

For Sale Very Cheap, a Brashear 8½ inch mirror and flat, two eyepieces, mount with rack and prism. The mirror is perfect, being just re silvered by Mr. Brashear. Inquire at the office of POPULAR ASTRONOMY.